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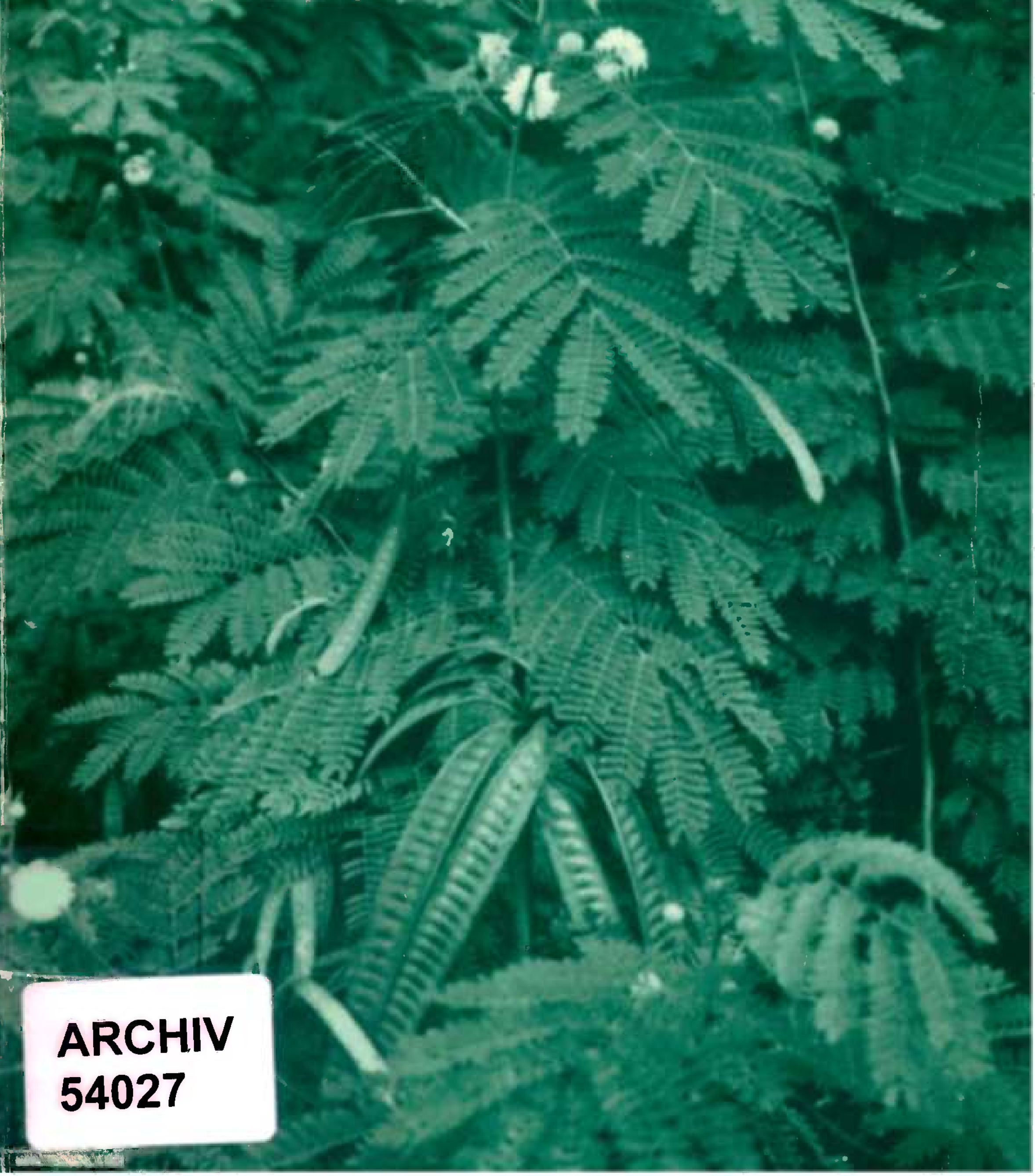
Leucaena Research in the Asian-Pacific Region

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



Leucaena Research in the Asian-Pacific Region
IDRC-211e

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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa, Canada

IDRC, Ottawa CA

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Leucaena Research in the Asian–Pacific Region

Proceedings of a Workshop Held in Singapore, 23–26 November 1982

Organized by the Nitrogen Fixing Tree Association and the International Development Research Centre

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

Research on Leucaena Wood at the Forest Products Research and Development Institute (FPRDI), Philippines

Pancracio V. Bawagan *FPRDI, College, Laguna, Philippines*

The Forest Products Research and Development Institute got involved in research on the utilization of wood from giant leucaena in 1973 in response to the need expressed by several wood-industry companies and entrepreneurs. This paper presents some of the results of studies on proximate chemical composition; specific gravity and calorific value; fibre morphology; mechanical properties; lumber recovery; parquet flooring; kiln drying of lumber and poles; preservative treatments; particleboard; hardboard; dissolving pulp; paper pulp; charcoal; and fuelwood for dendrothermal power plants.

L'Institut de recherches et de développement des produits forestiers (FPRDI) a entrepris, en 1973, des études sur l'utilisation du bois de Leucaena géant pour répondre aux demandes de plusieurs membres et entrepreneurs de l'industrie du bois. Cet exposé rapporte divers résultats d'études sur les sujets suivants : composition chimique approximative du bois ; poids spécifique et valeur calorifique ; morphologie de la fibre, propriétés mécaniques, proportions de bois de construction, parquets en bois, séchage au four du bois d'oeuvre et des poteaux, panneaux de particules ; panneaux de fibres durs ; traitement de préservation ; pâte à dissoudre ; pâte à papier ; charbon de bois ; et bois de chauffage pour les centrales dendrothermiques.

El Instituto de Investigación y Desarrollo de Productos Forestales (FPRDI) se involucró en la investigación sobre utilización de madera de Leucaena gigante en 1973 como respuesta a la necesidad expresada por varias industrias madereras. Este trabajo presenta algunos resultados de los estudios sobre composición química proximal, gravedad específica y valor calórico, morfología de la fibra, propiedades mecánicas, recuperación de maderos, pisos de plaquetas, secado en horno de maderos y postes, tratamientos de preservación láminas prensadas, disolución de pulpa, pulpa de papel, carbón y combustible para plantas de energía dendrotérmica.

The Forest Products Research and Development Institute (FPRDI) began researching the utilization of giant *Leucaena leucocephala* (locally called ipil-ipil) in 1973 in response to requests by several wood-industry companies and entrepreneurs. Subsequently, financial assistance was provided by the National Science and Technology Authority (NSTA) and the Philippine Council for Agriculture and Resources Research (PCARR). This paper presents some results of the research.

Wood Properties

Escolano et al. (1978) analyzed the chemical composition of seven samples of giant leucaena from different sources, as well as that for the native leucaena and the Philippine mahogany group (average of seven species). The ranges for the giant leucaena samples were 69.8–73.9% holecellulose, 8.9–20.1% pentosans; 21.8–26.0% lignin; 13.0–16.4% caustic soda solubles; and 0.7–0.9% ash. These data indicate that the giant leucaenas (Peru and K28) would be better raw material for pulp-and-paper manufacture than the Philippine mahogany woods or the native leucaena.

Laxamana (1981) tested the specific-gravity and heating values for the wood of seven varieties of giant leucaena and reported that a 5-year-old Peru variety had the highest (0.665) specific gravity and a 1-year-old K28 had the lowest (0.379). As K28 matures, however, its specific gravity increases: 0.518 at 2 years; 0.569 at 4–5 years; and 0.634 at 6 years. In comparison, the native variety has a specific gravity of 0.73 (Rocafort et al. 1971).

The heating values of the seven varieties ranged from 4.0 kcal/g in a 2-year-old K28 to 4.3 kcal/g in a 2.5-year-old Mexican variety. Apparently, the common variety also has a higher heating value (4.6–4.7 kcal/g) than the giant varieties (Aguilar 1943).

The fibre dimensions of giant and native leucaena were reported by Tamolang et al. (1957). The values are typical of those of hardwoods and are within the ranges for those obtained for various Philippine hardwoods. The average fibres of the giant samples are longer than those of the native leucaena but shorter than those of Philippine mahogany species.

Standard tests of the mechanical properties of leucaena were reported by Floresca et al. (1978). The tests were done on green, clear specimens taken from two trees of giant leucaena with average diameters of 18 cm and 15 cm at the butt and top portions, respectively, and about 549 cm long. These trees were obtained from Canlubang, Laguna. The results were compared with the strength properties of seven Philippine mahogany (PM) species, which are commonly used for stonecut sidings and tongue-and-groove flooring, and with those for seven species of *Dipterocarpus*, or apitong group, most commonly used for rafters and roof trusses. The findings were that:

- The strength properties of giant leucaena exceeded those of tiaong (*Shorea agsaboensis)*, the weakest PM species in every measurement except modulus of elasticity in compression parallel to the green (85% of that for tiaong). Compared with bagtikan *(Parashorea plicata)*, the strongest of PM species, the leucaena was inferior in all strength properties.
- Compared with the weakest of the apitong group (*D. warburgi*), leucaena was inferior in strength properties, i.e., 79% for modulus of elasticity in bending, 99% for stress at proportional limit in compression, and 70% for modulus of elasticity in compression. Compared with the strongest of the apitong group (*D. grandiflora*), it was inferior in all properties except compression perpendicular to the grain, hardness, and shear.

As the study on strength properties of giant leucaena was conducted on only two trees obtained from Canlubang, Laguna, the authors (Floresca et al. 1978) considered the findings as tentative but considered the strength properties of giant leucaena, in this particular case, as comparable with some species of both *Dipterocarpus* and Philippine mahogany.

Potential Uses

Studies on giant leucaena conducted at FPRDI, using the 1300-mm bandmill with a gauge-16 blade with stellite-tipped teeth, showed lumber recoveries of 56% and 61% from 5-year-old and 7-year-old trees, respectively, from Canlubang, Calamba, Laguna (Eala and Ortiz 1978). The five logs (diameter 22–25 cm, 1.52–1.89 m long) from the 7-year-old trees were sawn into a nominal thickness of 2.54 cm and various widths. The recovery figures were lower than those obtained by commercial bandmills in Metro Manila at 68% of log volumes (Decena et al. 1970), probably because the bandmills were processing larger logs.

Using wood hardness and shrinkage behaviour as suitability indicators for parquet flooring material, Eala and Salita (1981) reported that giant-leucaena wood appeared to be comparable with the traditional species (*Pterocarpus indicus*, *Shorea polysperma*, and *S. guisok)* being used (Table 1). One cubic metre of logs (input) of 4-year-old giant leucaena trees produced 22 m^2 of parquet materials (fillets of 2.54 cm × 12.7 cm × 1 cm).

Drying of 25- and 50-mm thick giant leucaena lumber and round poles was investigated under various drying methods by Laxamana (1981) who found that both K28 and the Peru variety were relatively easy to season. Predrying either in the sun or by forced air mechanisms shortened kiln-residence time, thus saving energy as well as producing better-quality dried materials.

Barrel check, along the round pole surface, warping, and surface checks in some 50-mm thick sawn boards occurred in kiln drying. These defects could be minimized by careful, slow drying.

Table 1. Suitability of four woods as parquet material.

	Hardness (kg)		Specific gravity	Shrinkage (%) Radial		Shrinkage (%) Tangential	
	End	Side		G-12	G-OD	G-12	G-OD
L. leucocephala	815	710	0.62	2.4	4.8	5.0	8.4
P. indicus	446	423	0.53	0.9	2.7	1.4	4.0
S. polysperma	260	262	0.44	2.0	3.6	4.0	7.6
S. guisok	854	682	0.80	2.8	5.9	6.0	10.4

Three varieties of leucaena, K28, K8, and Peru, were given five preservative treatments, and the results were reported by Siriban et al. (1981).

In the first treatment, specimens measuring 50 mm × 76 mm × 460 mm with an average moisture content of 78.6% were brushed with 30% boron-flouride-chromium-arsenic (BFCA) solution, wrapped in polyethylene bags, and left for 1, 2, and 3 weeks.

Tests showed an average penetration of 2.8 mm in the 2- and 3-week diffusion periods. The heartwood was totally unpenetrated. The extent of penetration was considered sufficient to protect the specimens from insect infestation and decay.

In the second treatment, specimens were immersed in a tank containing 8% copper sulfate for 7 days and then transferred to another tank with 8% potassium dichromate for another 7 days. Results showed a penetration 9 mm deep in the sapwood — a depth that was considered sufficient to protect lumber not exposed to weather.

The third treatment was a hot-and-cold bath. Specimens were heated in a bath of 50 : 50 creosote–bunker-oil solution for 2, 4, and 6 h at 100°C and then subjected to a cold-bath treatment for 2, 4 h, or overnight. Specimens hot-bathed for 2 h and cooled for 2 h had an average side penetration of 4 mm. Prolonged hot-and-cold bath treatments did not produce as satisfactory penetration as did the other treatments.

Specimens in the fourth treatment, i.e., pressure treatment — full-cell process — showed that the heartwood is moderately difficult to treat and the sapwood easy to treat, with an average retention of 314 kg/m³. The green sapwood was especially easily and effectively treated by high-pressure sap displacement, the fifth treatment, with retentions that were much better than those for conventional pressure treatments.

Pablo et al. (1981) reported that giant leucaena particleboard, comparable with that from other medium-density species tested at FPRDI, could be made from both debarked and partially degraded leucaena logs (Table 2). When resin content was increased from 8% to 9% and the particle size increased to 0.62 mm, the properties of the particleboard prepared from partially degraded logs were improved.

A more recent study (Generalla 1982) showed that, at 8% resin content, density of fine-surfaced boards would have to be 0.7 g/cm³ and 0.6 g/cm³ at bending strength of >180 kg/cm² and 130–180 kg/cm² respectively, whereas, for flake-type homogeneous boards with bending strength of >180 kg/cm² and 130–180 kg/cm², the density would have to be 0.65 g/cm³ and 0.60 g/cm³, respectively.

Table 2. Average mechanical and physical properties of urea-formaldehyde-bonded giant leucaena particleboards (density 650 kg/cm³).

	Good-quality chips[a]	Low-quality chips[b]
Chip thickness (mm)	0.33	0.62
Resin content (%)	8	9
Modulus of rupture (kg/cm²)	171	176
Internal bond (kg/cm²)	4.7	4.3
Thickness swelling (%)	26	16

[a] From freshly felled, debarked material.
[b] From partially degraded materials with bark.

In 1975, Semana and Lasmarias reported a study of hardboard from 2.5-year-old leucaena (average length of trunk 5.2 m, average diameter at butt 14.4 cm, specific gravity 0.59) from Davao City. The wet process was used to convert the wood to hardboard; pulping was done in a laboratory Asplund defibrator (yield 94.2%) and then processed in a disc refiner to a freeness of 24.0 seconds (defibrator seconds).

The authors concluded that the hardboards from the Peru variety could meet the specifications for US standard-type hardboards and would be equal in quality with the ones produced locally from other species.

Inciong et al. (1978) tested giant leucaena wood in the production of dissolving pulp, incorporating both debarked and barked samples in the study. Their results indicated that water prehydrolysis (first stage) and kraft pulping (second stage) at 15.60 and 18.22% active alkali and 25% sulfidity produced easily bleachable chemical pulp from the leucaena. Alpha-cellulose content was high (92.08–96.68%), and yield ranged from 35.33% to 46.02%. However, the multistage bleaching processes that were employed in this study proved to be ineffective, resulting in reduced alpha-cellulose content. An earlier study (Bawagan and Villanueva 1976) had found that a five-step bleaching process — chlorination, alkali extraction, addition of hypochlorite, alkali extraction, and addition of chlorine dioxide — was effective, but this process was not tested by Inciong et al. (1978).

Kraft-pulping studies are being conducted by Semana et al. (1981a,b) on 1- and 2-year-old K8, K28, K67, Peru, and COPIL varieties of leucaena. Screened pulp yields have ranged from 49.5% to 50.6% for the 1-year-old stems and from 48.6% to 50.5% for the 2-year-old stems. These values compare favourably with those obtained from other reforestation species like *Anthocephalus chinensis* and Moluccan sau, although strength properties of the pulp handsheets were slightly inferior, notably in tensile strength. Of the five strains, K8 and K28 exhibited the best strength properties.

Fuel

I (1982) have recently reported studies of charcoal production from giant leucaena wood. The 2-year charcoaling operation was conducted in four beehive oven prototypes that were being compared in the study. (One of the prototypes — the one developed by FPRDI staff — is now being used commercially to produce charcoal from sawmill waste and giant leucaena.) The data collected were the volume of wood charge, charcoaling cycle time, the volume and weight of charcoal produced per cycle, and charcoal yield. The proximate chemical composition of the charcoal produced showed 79.5–84.7% fixed carbon and 10.8–17.5% volatile matter.

The technical and economic feasibility of using plantations of giant leucaena and other fast-growing wood species for wood-fired, steam power plants was studied by FPRDI from 1974 to 1979 (Semana et al. 1977; Bawagan and Semana 1979, 1980; Semana and Bawagan 1979). The findings were that, at crude-oil costs of US$ 18 barrel, the production cost of a 75-MW, oil-fired steam power plant would be US$ 0.038/net kWh compared with US$ 0.026–0.074/kWh for dendrothermal steam-powered plants of 10–75-MW capacity. At a higher cost of oil (US$ 37/barrel), even a 10-MW, wood-fired plant would be competitive with the 75-MW, oil-fired plant. It was shown, further, under Philippine conditions, that combining a dendrothermal power plant with fuelwood plantation would be better than operating an oil-fired power plant because of the employment generated and foreign-exchange conserved. The National Electrification Administration (1982) has announced commercial power-generation programs for 1982–87, resulting in a total capacity of 200 MW.

Plans are for 7.0×10^4 ha to be reforested, 11 000 jobs created, 60–70 power plants constructed from foreign (US$ 220 million) and local funding (US$ 120 million). A yearly saving of 1.75 million barrels of oil-energy equivalent is expected. To the year 2000, the target is 2000 MW of electricity-generation capacity from fuelwood, the corresponding land area to be reforested being 7.0×10^5 ha.

Conclusions

Basic information on leucaena wood such as the proximate chemical composition, specific gravity, calorific value, fibre morphology, and mechanical properties provides some indication of potential uses but should be validated. FPRDI has undertaken some of the necessary tests, examining lumber recovery, parquet flooring, drying of lumber and poles, preservative treatment, particleboard, hardboard, dissolving pulp, paper pulp, and charcoal. The question of which among these various possible uses of leucaena wood is most promising in terms of profitability, investment requirements, and economy of scale for commercialization in a given set of conditions has yet to be answered and should be the subject of a comprehensive feasibility study.