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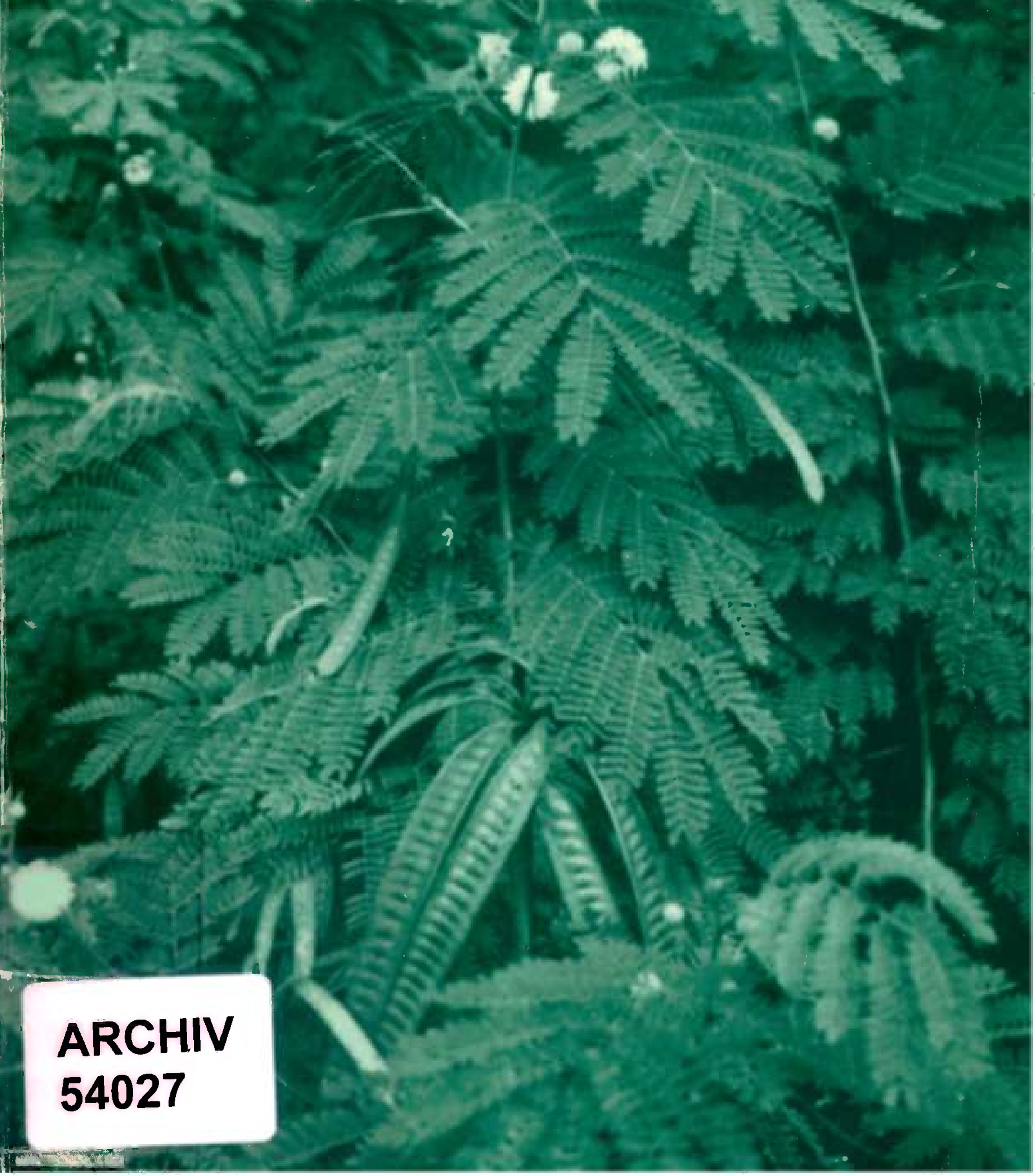
Leucaena Research in the Asian-Pacific Region

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



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Leucaena Research in the Asian–Pacific Region

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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Leucaena leucocephala as a Tall Cover Crop for Sawlog Plantations

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Leucaena leucocephala *seldom exceeds 20 m high and usually stops growing at 15 m or less in most sites in Malaysia. Hence, it is too small to be a sawlog species. However, because it is fast growing, it may play a useful role as a tall cover crop in sawlog plantations where the sawlog species is expected to grow to 30 m or more. Preliminary results of trials with* L. leucocephala *as a cover crop for teak and* Araucarla *sp. have proved promising.*

Leucaena leucocephala *dépasse rarement 20 m de hauteur et sa croissance s'arrête généralement à 15 m ou moins dans la plupart des régions de la Malaisie. Il est donc trop peu important comme bois de sciage. Cependant, comme il pousse rapidement, il peut être utile comme haute formation végétale de couverture pour de jeunes peuplements d'espèces destinées au sciage et dont la hauteur pourra atteindre 30 m ou plus. Des premiers essais utilisant* L. leucocephala *comme couverture pour le teck et* Araucarla *se sont révélés prometteurs.*

La Leucaena leucocephala *raramente excede 20 m de alto y generalmente se detiene a los 15 ó menos en la mayor parte de Malasia. Por tanto, es demasiado pequeña para ser una especie de aserrío. Sin embargo, como es de crecimiento rápido, puede desempeñar una función útil como cobertura alta en las plantaciones de madera de aserrío, donde se espera que las especies crezcan 30 m ó más. Resultados preliminares de las pruebas con* L. leucocephala *como sombrío para la teca y la* Araucarla *han sido promisorios.*

Monospecific vegetation is more unnatural in the humid tropics than anywhere else in the world, and to maintain nonspecific tree plantations requires the continual input of energy in the form of labour, herbicides, and pesticides. Any relaxation results in weed invasion and proliferation.

Although the effects of weeds are not all negative — for example, they help to protect the soil from exposure and degradation wherever the crop itself fails to form a protective cover — they often compete and suppress crops because of their greater vigour and better adaptation to a site.

One way to minimize weeds, maximize crop production, and simultaneously to provide cover is to plant at very close spacing. Then, the crop can utilize space, soil resources, and sunlight. This approach is widely adopted for short-rotation crops such as rice. Nevertheless, one species cannot be planted repeatedly on the same site without a steep decline in yield. Such decline is usually attributed to selective exhaustion of nutrients by the species concerned and to buildup of pathogens of that species. Hence short-rotation crops are usually grown in sequence with one or more other species, of which one is usually a nitrogen-fixing legume.

For long-rotation crops, such as trees, however, close planting and sequential cropping cannot be practiced for two reasons. First, the space requirements of a healthy tree increase each year until maturity, and a mature tree is enormous compared with its seedling. Hence, there is no single spacing that is suitable for the whole economic life of a monospecific tree plantation. Second, a long-lived crop may suffer from soil exhaustion and pathogen buildup before it is due to be rotated with another species.

Two different approaches to solving the problem can be seen in Malaysian arboriculture. One is traditional, characterized by multispecies composition, multistoried canopy structure, and uneven-aged trees. Such arboriculture, mostly of fruit trees, has endured for centuries without the application of modern pesticides and chemical fertilizers and without intensive labour. The multistoried canopy reduces the light at ground level to an intensity too low for the more aggressive weeds to thrive. The multispecies composition, and individual replacement of old trees by young ones through underplanting, effectively substitutes for crop rotation.

Traditional arboriculture produces a multiplicity of products in a diffused manner. Modern arboriculture, as exemplified by rubber, oil-palm, and cocoa plantations in Malaysia, however, is industrial, geared to producing a single product. The conveyor belt may not be a part of the operation, but the conveyor-belt concept is very much in evidence. The trees are planted at the same age, in a uniform spacing designed to accommodate mature trees, with plenty of space for weed proliferation until the trees achieve canopy closure. Weeds are preempted, however, by the deliberate cultivation of a legume species to provide cover. The modern rubber or oil-palm plantation is, therefore, not truly monospecific. It is a two-species association — a tree with a leguminous herb. Although the legume component is normally referred to as the "cover crop," the relationship between the two components is dynamic, with the legume playing the main cover role in the beginning, gradually being phased out under the shade of the growing trees, and disappearing when the trees form a closed canopy. At the final stage, the trees provide the main cover, and the legume is naturally succeeded by shade-tolerant vegetation, among which are herbs, shrubs, as well as juvenile trees. The producers systematically eliminate shrubs and juvenile trees mechanically or by poisoning so as to prevent reversion to forestlike conditions.

Crop-Management Concepts in Silviculture

Natural tropical forests are multispecific, multilayered, and uneven-aged in composition. The multiple and highly varied products from such forests do not lend themselves easily to standardized procedures in harvesting, processing, promotion, marketing, or utilization. Monospecific timber plantations, therefore, have a great deal of attraction, particularly when linked to the promise of higher growth rates and shorter rotation times. Hence, most tropical forestry organizations have experimented with monospecific plantations, and some have launched ambitious plantation schemes.

In practice, there are two different approaches to the establishment of tropical timber plantations. The first approach is underplanting within logged-over forests. After the removal of commercial timber trees, a considerable amount of vegetation is left. Underplanting involves opening lines or gaps in such logged-over forests and planting seedlings of particular species, either in single lines or in clusters. The existing natural vegetation is cleared only enough to allow overhead light to reach the planted seedlings; the bulk of existing vegetation is left as a "matrix" that serves as a cover to protect the soil, as a nurse to provide some shade for the planted seedlings, and as a "filler" to provide a certain amount of crowding so that the planted seedlings are forced to elongate and produce 1–3 log lengths of clear bole before spreading their crown. The major difference between a plantation for sawn timber and other plantations is the emphasis on the development of a long clear bole, which is the final product and main objective of management.

In other words, timber plantations require a different sort of cover crop — one that simultaneously protects the soil between the planted timber trees, provides the necessary degree of crowding to stimulate vertical growth, provides partial shade for optimum growth of timber species in the juvenile stages, and suppresses weeds without itself being a weed. We refer to this sort of cover crop as a tall cover to differentiate it from the groundcover that is normally associated with the cover-crop concept.

The management of a tall cover provided by natural vegetation in logged-over forests is not easy because neither the height of the cover nor the density of foliage is uniform. As a result, the size of the clearing to be made around the planted seedlings is usually decided arbitrarily, the intention being that overshadowing will be prevented by periodic cleaning and clearing operations. The real drawback in this approach derives from the fact that the timber species best suited for such management have rotations of 50–80 years, according to silvicultural studies (Wyatt-Smith 1963). This is considered too long for conventional economic planning and investment.

One means to satisfy all the requirements is to plant fast-growing timber species. These are usually species with pioneer characteristics that establish on open ground. The pioneer species suitable for timber plantations are the giants such as *Tectona grandis*, *Gmelina arborea*, *Pinus caribbaea*, *Eucalyptus* spp., *Albizia falcataria*, and *Acacia mangium*. For sawlog production, a straight cylindrical bole of low taper is preferred. Having cleared the land to plant such species, one must still provide cover for the land, control weeds, and provide for controlled crowding. The traditional practice in monocultural timber plantations is to plant close and to thin the crop in stages. In other words, the crop species is expected simultaneously to cover the soil, shade out weeds, provide mutual crowding, and produce timber. Is this realistic? Trials on spacing requirements suggest that it is not. Numerous trials have been carried out to determine the optimum spacing for each timber species, but the results have nearly always been inconclusive.

To provide cover from the start, the trees must be so close together that the number of seedlings planted far exceeds the number of mature trees in the final crop. For example, square spacing, starting at 1 m × 1 m and ending with crop maturity at 8 m × 8 m, would involve 10 000 seedlings/ha, thinned progressively to 156 trees/ha. This enormous rate of attrition, although planned and deliberate, puts tremendous strain on any stock-production program and discourages the wider use of expensive, genetically improved stock. Furthermore, there is a fundamental contradiction because genetic improvement for timber trees involves selection for early development of clear bole at the expense of lateral branching, thereby reducing the ability of such trees to act as a cover. Compromise spacings using 2 m × 2 m (2500 seedlings/ha) or 3 m × 3 m (1111/ha) at the start open the way for weed proliferation in the critical early years of plantation establishment, and the trees still need to be thinned.

The solution to the problem appears to lie in separation of functions. The timber species should be selected and managed for timber production. Other species should be selected and managed as the cover crop. The acceptance of this solution would clear the way for specification and testing of tall cover crops (Ng 1980).

Specifications for a Tall Cover Crop

The principles for improving a timber tree are well known, but those for a tall cover crop need to be defined. One property that would be essential is low-cost seeds, seedlings, and establishment compared with the timber species. The species should also be able to:

- Establish under the same ecological conditions as the timber crop so that the two can be planted together;
- Shade out light-demanding weeds and provide cover for soil without suppressing the timber species;
- Grow to the required clear-bole height of the timber species but not taller;
- Improve soil, e.g., by fixing nitrogen; and
- Produce only small, easily decomposed, litter.

Other features are that it should not be able to tolerate shade so that it dies when outgrown by the timber species, and it should have no allelopathic or other inhibitory effect on the timber species.

One crop that was considered to have many of these characteristics is *Leucaena leucocephala*, so it was selected for trials as a tall cover crop with teak and araucaria in Malaysia.

Leucaena for Teak Plantations

In May 1980, 9.4 ha of teak and leucaena were planted in Mata Ayer Forest Reserve in the state of Perlis, Malaysia. The land was flat, low-lying (ca 50 m above sea level), and covered with early secondary growth, including *Imperata*, bamboos, and various herbaceous and shrubby weeds. The vegetation was slashed, the area plowed, and the teak planted at a spacing of 3 m × 3 m in the form of stumps (cleaned taproot topped by 1–2 cm stem). Hence, new shoot growth had to start from the ground. Leucaena seedlings (about 0.5 m tall) in containers were planted at the same spacing as the teak but alternated with it (Fig. 1). The minimum distance between plants (teak and leucaena taken together) was 2.12 m. Five sample plots, A–E, were laid out in different parts of the area so that growth could be monitored. Each plot was square and consisted of 6 × 6 teak trees and 7 × 7 leucaena trees. The trees were measured in October 1982, 29 months after establishment.

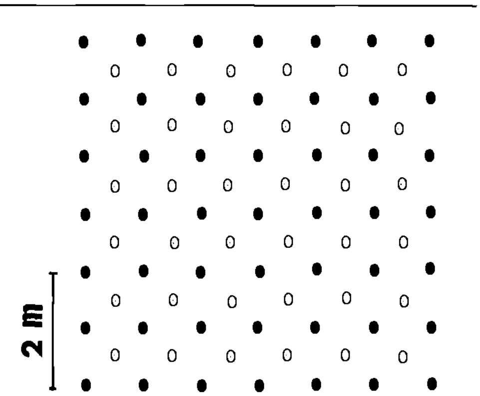

Fig. 1. Planting spacing for teak (○) and leucaena (•).

Table 1. Growth of *T. grandis* and *L. leucocephala* in mixed planting after 29 months.

	Plot				
	A	B	C	D	E
Teak					
Seedlings planted	36	36	36	36	36
Surviving plants	33	33	31	32	11
Mean height (m)	9.04	3.36	3.45	0.50	1.01
Standard deviation (height)	3.09	2.25	1.60	0.32	0.90
Leucaena					
Seedlings planted	49	49	49	49	49
Surviving plants	42	45	44	47	27
Mean height (m)	9.43	6.72	4.91	4.54	3.83
Standard deviation (height)	2.29	1.72	1.42	1.08	1.19

The height of teak (Table 1) indicated that site quality was extremely variable. On the best site, plot A, the teak and leucaena were about evenly matched in height and averaged slightly more than 9 m tall. In the other four plots, the performance of both species was depressed. Leucaena always outperformed teak, and the discrepancy between them was greatest where the teak performed worst. We concluded that site quality rather than incompatibility between the two species was responsible for the depression because both species performed poorly on some sites and well on others.

The ability of the teak–leucaena combination to control weeds was not as good as hoped. On the best site (plot A), *Imperata* was effectively suppressed but, elsewhere, was still very much in evidence, although probably weakening in plots B and C. The worst weed was the legume twiner *Pueraria* sp., ironically introduced into the area in an earlier cover-crop experiment and now forming a doubly vicious weed association with *Imperata*. By climbing, smothering, and strangling, *Pueraria* can destroy any plants that manage to outgrow the *Imperata*. To survive, the saplings must be freed from *Pueraria* frequently.

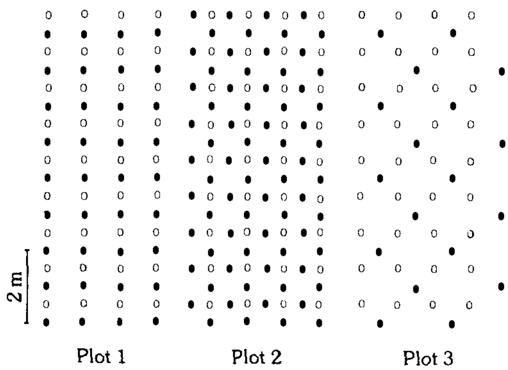

Fig. 2. Planting spacings for araucaria (◦) and leucaena (•).

Leucaena for Araucaria Plantations

Next to teak, the most highly regarded species for timber plantations in Malaysia is *Araucaria hunsteinii*. Seeds are imported from Papua New Guinea and are not only expensive but also in very short supply. Conventional close planting and thinning would be unthinkable for such a species.

In a small experiment in Sungei Buloh, near our Institute at Kepong, seedlings of *A. hunsteinii*, about 0.75 m tall, were planted at 3 m × 3 m spacing in October 1980, on low-lying (30–46 m above sea level) land that had a history of food-crop cultivation, cattle grazing, burning, and *Imperata* infestation. Seedlings of *L. leucocephala*, about the same height as the araucaria, were interplanted with the latter in three different intensities (Fig. 2) such that the ratio of araucaria to leucaena was 1 : 1; 1 : 2; and 2 : 1. Three rectangular plots of 9 × 4 araucaria trees were demarcated, and measurements were made in October 1982, at age 2 years (Table 2).

The leucaena was always taller than the araucaria. Plot 3, with plants at the lowest density, produced the worst growth for araucaria but best growth for leucaena. The most favourable planting design for araucaria was that of plot 1, which had the advantages of producing good growth in both araucaria and leucaena, having a neat appearance, and being lower in cost of planting than plot 2.

Imperata was effectively checked in all three plots, but several species of cover-crop legumes were introduced as seeds into the

Table 2. Growth of *A. hunsteinii* and *L. leucocephala* in mixed planting after 24 months.

	Plot		
	1	2	3
Araucaria			
Seedlings planted	36	36	36
Surviving plants	26	30	24
Mean height (m)	2.06	1.92	1.62
Standard deviation (height)	0.56	0.49	0.46
Leucaena			
Seedlings planted	36	72	18
Surviving plants	28	42	11
Mean height (m)	4.60	3.57	6.05
Standard deviation (height)	0.84	0.96	1.97

plots in January 1981. These were *Pueraria phaseoloides*, *Centrosema pubescens*, *Calopogonium caeruleum*, *C. mucunoides*, and *Stylosanthes gracilis*. By October 1982, the *Stylosanthes*, a small erect herb, had virtually disappeared, but the others, especially *Pueraria* and *Centrosema*, had become serious weeds, requiring frequent cutting and threatening to strangle and smother the araucaria and leucaena.

Auraucaria–leucaena interplanting trial in Sungei Buloh Forest Reserve, Selangor, at 24 months.

Discussion

Although the experiments have not yet been completed, we can begin to assess the potential of leucaena as a tall cover crop for timber plantations, according to our list of specifications:

- Leucaena trees produce seed prolifically; the seeds are easy to harvest, store, transport, and germinate. Seedlings are easily raised and planted out. The cost per seedling planted is a fraction of the cost for teak and araucaria.
- Leucaena prefers open conditions and can be established together with other fast-growing, light-demanding species.
- Leucaena has a diffuse canopy that does not appear to inhibit teak or araucaria. On good sites, the teak–leucaena combination suppresses *Imperata* within 2 years. On poor sites, this combination is rather ineffective at the spacing used (ca 2 m between plants) because of depressed crown development in both species; juvenile and stunted teak, because of its unbranched, or sparsely branched habit, is particularly ineffective in providing cover. The araucaria–leucaena combination casts denser shade and is better at *Imperata* suppression because araucaria bears multiple tiers of branch foliage.
- Other observations (Norani and Ng 1981) indicate that leucaena is very variable in height, depending on site conditions. To be useful as a tall cover crop, it must reach a minimum of 10 m. This has not yet been achieved in 29 months.
- As for being self-limiting in height, leucaena is unlikely to exceed 15 m under most Malaysian site conditions.
- The gradual elimination of leucaena by teak or araucaria has not yet happened in our 24–29-month-old trials but may be expected within 5 years of plantation establishment, depending on site conditions.
- The nitrogen-fixing ability of leucaena is already recognized.
- Leucaena produces the finest and most easily decomposed leaf litter that can be expected.
- And it does not appear to have an inhibitory effect on either teak or araucaria.

Another possible specification for a tall cover crop is the ability to produce an economic product in its own right, e.g., fuelwood, food, fodder, etc. Such a specification would lead into agroforestry, which is not the subject of this paper. Nevertheless, leucaena also conforms to this criterion.

We have not focused on the potential agroforestry applications because, in Malaysia, the need for multiple products is less great than the need to protect plantation silviculture from the dangers inherent in monoculture (exemplified in *Gmelina* cultivation in Brazil and *P. caribbaea* in Malaysia).

We think that the promise of faster economic returns from plantation forestry cannot be realized without a strong genetic program to produce superior stock, coupled with ecologically sensible management of soil and space. As genetically superior plants should not be used wastefully and as monoculture involves high maintenance costs because of its ecological disequilibrium, it follows that the initial spacing of timber trees should be as close to final spacing as possible and that unutilized space should be densely planted with a suitable tall cover. Leucaena may or may not prove ultimately to be the tall cover that is needed, but the search needs to be continued.