TROPICAL ACACIAS: THEIR DOMESTICATION AND CONTRIBUTION TO ASIA'S WOOD AND PULP INDUSTRIES

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SUMMARY

About 1000 species of *Acacia* are native to Australia and neighbouring countries. Commercial plantations and smallholder woodlots have been established with three tropical acacia species, *Acacia auriculiformis*, *A. crassicarpa* and *A. mangium* and a hybrid, *A. auriculiformis A. mangium* (referred to as Acacia hybrid) and these are the focus of the current planting programmes. Over 1.8 Mha have now been planted in China, Malaysia, Indonesia, Papua New Guinea, the Philippines, Thailand, Vietnam, and in Melville Island in Australia.

Most of these estates are used as feedstock for Kraft pulp mills and significant quantities of wood are now finding their way into markets based on high-value solid timber.

Acacia mangium was first planted as an exotic in Malaysia 1966 and *A. crassicarpa* in China and Thailand in the early 1980s and their emergence as important commercial trees represents a major success in tree domestication. This paper traces the domestication of these species and the contribution they are making to regional wood supplies.

Keywords: Tropical Acacias, plantations, species domestication

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ACACIAS TROPICALES: SU DOMESTICACIÓN Y CONTRIBUCIÓN A LA INDUSTRIA DE PULPA Y MADERA EN ASIA

RESUMEN

Alrededor de 1000 especies de *Acacia* son nativas de Australia y países vecinos. Plantaciones comerciales y también de pequeños propietarios han sido establecidas con tres especies de acacias tropicales; *Acacia auriculiformis*, *A. crassicarpa*, *A. mangium* y un híbrido *A auriculiformis x A mangium* (a la que se hará referencia como acacia híbrida). Estas especies son el foco de los actuales programas de forestación. Más de 1,8 MM ha han sido plantadas en China, Malasia, Indonesia, Papúa Nueva Guinéa, Filipinas, Tailandia, Vietnam y en Melvilla Island en Australia.

La mayor parte de estos recursos son usados como materia prima en plantas de pulpa Kraft y volúmenes significativos de madera también están encontrando mercados basados en madera sólida de alto valor.

Acacia mangium fue inicialmnet plantada como una especie exótica en Malasia en 1966 y *Acacia crassicarpa* en China y Tailandia a principios de los 1980s y su emergencia como importantes árboles comerciales representa un importante éxito en domesticación de especies. Este trabajo describe la domesticación de estas especies y la contribución que hoy representan en el abastecimiento de maderas en la región.

Palabras claves: Acacias Tropicales, plantaciones, domesticación de especies.

INTRODUCTION

The genus *Acacia* consists of about 1300 species in three subgenera: *Acacia*, *Aculeiferum* and *Phyllodineae*. About 1000 species of *Acacia* (almost all in subgenus *Phyllodineae*) are native to Australia and neighbouring Indonesia, Papua New Guinea (PNG) and some Pacific Island nations. As over 95% of these species are endemic to Australia, they are referred to collectively as 'Australian acacias' (Midgley and Turnbull, 2003). Some of the tropical Australian acacias are now used in commercial plantations in south-eastern Asia and have created the basis for substantial plantation-based industries. Within this region, plantations of tropical acacias have been established in China, Malaysia, Indonesia, Papua New Guinea, the Philippines, Thailand, Vietnam, and in Melville Island in Australia. Three tropical acacia species,'*Acacia auriculiformis*, *A. crassicarpa* and *A. mangium* and a hybrid, *A. auriculiformis* ◊ *A. mangium*'(referred to as *Acacia* hybrid), are the focus of the existing plantations and current planting programmes. The total area planted exceeds 1.8 Mha (Table 1) with *A. mangium* being the dominant species with about 1.5 Mha.

Most of these estates are used as feedstock for mills to make Bleached Hardwood Kraft Pulp (BHKP) and now significant quantities of wood are finding their way into markets based on high-value solid timber.

Table 1
THE TROPICAL *ACACIA* PLANTATION ESTATE IN ROUND FIGURES

Country	Area (1 ,000 ha)
Australia	10
Brazil	40
China	40
India	30
Indonesia	1200
Malaysia	200
Papua New Guinea	10
Vietnam	300–400

ACACIA PULPS

Acacia pulp is bright and white and suitable for tissue, fine paper, bible paper, directory stock, envelope paper and carbonless base paper. Tropical acacia pulps are typically short-fibred (0.7 – 1.0 mm), of high density (22 million fibres per gram) and compete in international markets for Bleached Hardwood Kraft Pulps (BHKP). They provide a pulp with very high density of very short fibres, which give smoothness and high levels of opacity (Roberts, 2002).

In 1995, the first trial shipments of acacia pulp were presented to the European market. Since that time the amount of pulp available internationally has increased steadily. In 2002, the large Indonesia producers, Asia Pulp and Paper, APRIL, PT Tel and Kiani Kertas increased production to an estimated 1.9 million tonnes and if expansion plans are achieved and the Indonesian pulp sector becomes largely plantation-based, the quantity of acacia pulp on the international market could grow to in excess of 4 million tonnes by 2010.

Current spot prices for tropical acacia pulps (US$ 610 per tonne at August 2006) would place the value of tropical acacia pulp at about US$ 2.5 billion in 2010 if production targets are met and prices maintained.

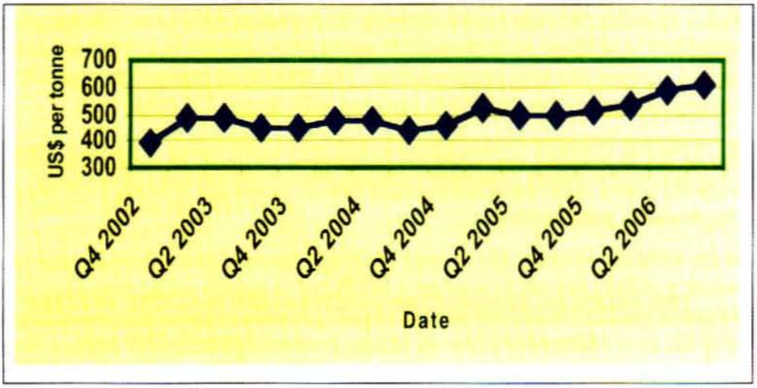


Figure 1
SPOT PRICES ACACIA KRAFT PULP 2002 - 2006

Pulp yields vary within species and between the two major commercial species *A. mangium* and *A. crassicarpa*. Typically, the basic density of *A. crassicarpa* (500 – 540 kg/m^3) is greater than that of *A. mangium* (450 – 500 kg/m^3) but the pulp yields are slightly lower; typically 51% for *A. crassicarpa* and 52.5% for *A. mangium*.

ACACIA AS SOLID TIMBER

Most tropical acacia timber used as solid wood is *A. mangium*. The timber is of medium density and can be sawn easily, planed to a smooth surface, polished, drilled and turned. The wood is fairly stable, and it dries without serious defects when suitable kiln schedules are used (Razali and Hamami, 1992, Abdul-Kader and Sahri, 1993). The wood is also stable, with shrinkage from fresh to air-dry of around 6.4% tangentially and 2.7% radially, and fibre that is relatively straight and only in certain cases is found to have interlocked grain (Yamamoto, 1998). It is very durable when exposed to weather but not in contact with the ground. The heartwood is moderately resistant to preservative treatment. It makes excellent particle board, and is suitable for furniture and cabinet-making, light structural works, agricultural tools, boxes and crates. It has been sliced for veneer and is frequently finger-jointed.

A large market for acacia wood is developing in Vietnam where it is a part of the country's booming wood products export business. In 2006, the value of exported finished wood products from Vietnam will reach US$ 2.1 billion (Fig. 2). In excess of 80% of the raw material for this valuable industry is imported, including *A. mangium* logs of Malaysian origin.

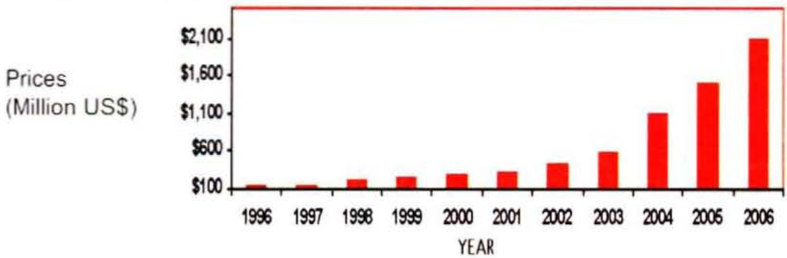


Figure 2
VIETNAM'S WOOD PRODUCTS EXPORTS

These sawlogs are small by Australian standards, rarely exceeding 30 cm dbhob and as small as 10 cm small-end diameter (sed).

The prices received at the mill gate for acacia logs in Vietnam are quite variable (Table 3). In 2003, prices were US$ 35–80 m^3. At one mill, a premium was paid for larger logs. The price being offered for acacia pulp wood during the same period was US$ 14–26 m^3. Imported logs of *A. mangium* from Malaysia were being landed at the port near Ho Chi Minh City for about US$ 85 m^3 which is the top end of the price range being offered for local logs at the mill gate.

As a pioneer in growing acacia, Malaysia is now a major exporter of acacia wood. Several companies actively export both logs and processed sawn timber. For example, log prices were around US$50 /$m^3$ and finger-jointed timber US$900 /$m^3$ FOB in 2005 (Table 2).

Table 2
SOME EXAMPLES OF THE MARKETING OF ACACIA WOOD IN MALAYSIA IN 2005

Company	Product	Capacity (per month)	Price (US$/ m^3 FOB)
High Quality Wood Sdn Bhd	Logs >20 cm sed	3000–6000 m^3	52
KD S4S lumber		10–50 containers	450–480
KD tiles		10–20 containers	490
KD finger-jointed laminated T&G timber		5–20 containers	900
Dagangan Hdn		Sawn timber in various lengths to 1 m	250
Amazon Timber Sdb Bhd		Air-dried sawn timber 2"–3" to 2 m length	230/ tonne
Indonesia (misc suppliers)		Kiln dried sawn lumber (Hardyanto, pers comm)	100

Prices are per cubic metre unless otherwise stated

Table 3
EXAMPLES OF PRICES PAID FOR ACACIA LOGS IN VIETNAM AND USED AS SOLID TIMBER FOR FURNITURE

Date	Site	Product	Price (US$/m³)
Apr 2003	Quang Tri	At farm gate: about 30 cm dbhob	43
Sep 2003	Hue	At mill gate: 15–20 cm sed	38
Sep 2003	Hue	At mill gate: 20–30 cm sed	45
Sep 2003	Hue	At mill gate: >30 cm sed	52
Sep 2003	Ho Chi Minh City	At mill gate: 20 cm sed	80
Sep 2003	My Xuyen (near Hue)	At mill gate: >20 cm sed	35–40
Sep 2003	Hue City factories	At mill gate: >20 cm sed	45–58

The data were provided mainly by provincial forestry officials, but were largely corroborated in the field.

TROPICAL ACACIAS AS EXOTICS

Tropical acacias are adapted to a wide range of site conditions in the seasonally-dry and lowland humid tropics. The first species to be planted extensively was *A. auriculiformis* and it has been planted as an exotic in Asia for more than 70 years. Introduced into Malaysia in 1932 and Thailand in 1935 it has since been planted widely. In India it has become a major plantation species and in China over 50,000 ha of plantations and 3,000 km of roadside plantings have been established. It was the introduction of *A. mangium* into Sabah, Malaysia, from Australia in 1966 that created the major interest in tropical acacias. Initially introduced as a plant in firebreaks to protect pine plantations, its rapid growth suggested its potential for wood production and early plantations were established in Malaysia (Yap, 1987).

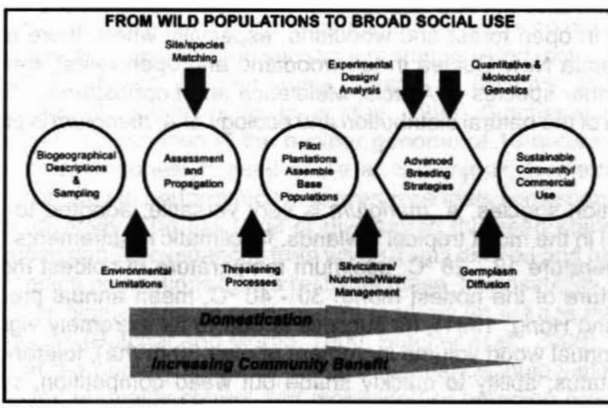
Based on the early introductions and success of *A. auriculiformis* and *A. mangium*, there was recognition in the 1970s and 1980s that other acacias had potential as highly adaptable, multipurpose trees to provide fuelwood and industrial wood for the tropics (e.g. Boland and Turnbull, 1981). This stimulated major exploration of the rich genetic resources of the genus in Australia and adjacent countries. In the early 1980s CSIRO, with the encouragement of FAO and support of various donor agencies (primarily the Australian Centre for International Agricultural Research) and with the cooperation of national research partners and land managers, began comprehensive seed collections of acacias in the humid tropics of Australia, Indonesia and Papua New Guinea (Turnbull *et al.*, 1983; Skelton, 1987; Searle, 1989; Gunn and Midgley, 1991) and a series of large-scale species elimination and provenance trials with partners in countries such as China, Thailand, Indonesia and Australia.

Acacia crassicarpa was identified as part of this process and since 1995 has developed into a commercial species, mainly in lowland Sumatra, Indonesia.

Natural hybrids between *A. mangium* and *A. auriculiformis* (*Acacia* hybrid) were recorded in Sabah by Sim (1987) with some displaying greater vigour, increased apical dominance, finer branching and greater pulp yields. In Vietnam, *Acacia* hybrid is now the dominant stock for planting because the best selected hybrid clones have been shown to have marked heterosis for growth in many regions of Vietnam (Kha, 2001). By the end of 2004 this species accounted for 127,000 ha in Vietnam and in 2004 alone 46,000 ha of the hybrid were planted (van Bueren, 2005).

DOMESTICATION

Figure 3 (adapted from Midgley 1995) illustrates the domestication process that is being applied wholly or in part to acacias. It is difficult to identify discrete stages because plant domestication is a continuum and progress through all stages might not be socially necessary or economically viable.



(Midgley, 1995)

Figure 3
THE PROCESS OF DOMESTICATION

The process of domestication which has seen *Acacia mangium* (since 1966) and *A. crassicarpa* (since 1984) come from obscurity, into experimental trials and become species of major commercial importance, has involved plantation managers and researchers from many countries.

The challenging process of exploration and manipulation of the wild genetic resource to derive uses and products for maximum social benefit is regarded as domestication. It is an ill-defined process but it has a clear beginning (the wild plant), a middle (human intervention via propagation, selection and manipulation) and an outcome (enhanced human benefit). It begins with the original variability in the natural forest and ends in productive plantations (Libby, 1973) and full tree domestication includes identification and characterisation of its germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems (Leakey and Newton, 1994).

In contrast to that of most agricultural crops, the principal domestication of trees has occurred in the last one hundred years and only a few species are significantly changed from their wild state. Intensive domestication programmes have been applied only to eucalypts, pines or other species with high value for products such as timber and paper.The rapid progress with the domestication of tropical acacias, particularly *A. crassicarpa* that was first planted in species trials in 1984, has been remarkable.

Domestication and Use of *Acacia mangium* Willd.

In its area of natural occurrence *A. mangium* is a large tree, to 30 m tall, with a straight bole, which may be over half the total tree height but rarely has a diameter over 50 cm. Most natural occurrences are in the coastal, tropical lowlands, usually at an altitude below 300 m. It extends from northern Queensland through the Western Province of Papua New Guinea into the Indonesian provinces of West Papua (Merauke District and Vogelkop Peninsula) and Maluku (Sula, Ceram and the Aru Islands). *A. mangium* grows on the margins of closed forest (rain forest), in open forest and woodland, especially where there is disturbance by fire. It occurs in Papua New Guinea in tall woodland and open forest, frequently in mixed associations with other species of *Acacia*, *Melaleuca* and *Lophostemon* (Skelton, 1987). A detailed description of the natural distribution and ecology of *A. mangium* is provided in Awang and Taylor (1993).

As a plantation species, *A. mangium* is very versatile, adapted to a wide range of acidic soils (pH 4.0) in the moist tropical lowlands. Its climatic requirements as an exotic are: mean annual temperature 18 - 28 °C, minimum temperature of coldest month 10 – 24 °C, maximum temperature of the hottest month 30 - 40 °C, mean annual precipitation 1000 - 4000 mm (Booth and Hong, 1991). Its success is due to its extremely vigorous growth on favourable sites (annual wood volume increment of over 30 m^3/ha); tolerance of acidic soils with low nutrient status; ability to quickly shade out weed competition, such as *Imperata* grass; relative freedom from diseases; wood properties which potentially make it acceptable for a wide range of end uses; and ease of establishment. Commercial pulpwood plantations are not usually thinned or pruned and are harvested at 6 - 7 years. Trees are harvested for sawlogs at 10 - 12 years.

Since the initial introduction to Sabah in 1966, extensive plantations were established in Malaysia and Indonesia after 1973 and much of the information on silviculture and utilisation of *A. mangium* comes from this region. The initial plantations were established using unselected wild genetic material so the domestication period has been relatively short, but the high value of the plantations and the pulp mills that they feed has resulted in intensive research since about 1980. Much has been learnt about the species in the last 25 years and has resulted in efficient silvicultural practices and the use of selected, highly productive germplasm, including hybrids, sometimes in clonal plantations.

- Sampling and Characterisation of Genetic Variation

Exploration of the natural distribution of *A. mangium* and the systematic collection of seed and botanical material took place mainly between 1980 -1990 and was described by

Gunn and Midgley (1991). The seed collections were used to establish international provenance trials to examine the patterns of genetic variation in growth rate, stem straightness and frequency of multiple leaders and the extent of genotype x environment interactions. The results of the early trials were reported by Harwood and Williams (1992). There were highly significant differences in performance between experimental sites (19), between provenance regions (5) and among the local provenances within provenance regions. Growth was generally faster at near-equatorial trial sites, with mean annual increment in height around 3 - 4 m, and slower at sites further from the equator. Papua New Guinea provenances consistently grew fastest, closely followed by the Claudie River provenance from far north Queensland. Significant gains were therefore possible simply by using seed from wild populations in selected localities.

In contrast to large differences in growth performance of families and provenances, allozyme studies indicate low levels of genetic variability within and between populations in this species (Moran *et al.*, 1989a). Harwood and Williams (1992) concluded that allozyme studies examine only a small sub-set of the genome, and therefore do not provide an absolute measure of overall genetic variation, and subsequent studies using restriction fragment length polymorhisms (RFLPs) detected higher levels of variation (Butcher *et al.*, 1998) and high levels of selfing in natural populations (Butcher et al., 1999). Butcher *et al.* (1996) also used RFLPs to assess genetic variation in the nuclear genome of 10 natural populations and a derived population (an Indonesian seed stand at Subanjeriji, Sumatra). The ranking of populations based on growth performance in provenance trials corresponded to the rankings based on genetic diversity. The low level of diversity in the seed stand reflected the low variation in the Queensland provenances from which it was derived and highlights the danger of establishing breeding populations from a restricted base. Microsatellite markers have been developed to provide highly variable co-dominant markers for linkage mapping and studies of the breeding system (Butcher and Moran, 2000; Butcher *et al.*, 2000). Molecular markers can aid selection at the nursery stage for disease resistance, pulp yield and wood density and provide a means of quality control and monitoring of breeding programs and Butcher (2004) has described the application of molecular technologies for acacias.

- Breeding

Following these trials, further comprehensive seed collections were undertaken and seedling seed orchards established to produce better quality seed for future planting programs. Breeding programs are now in place in China, Philippines, Vietnam, Australia, Indonesia, Thailand, Papua New Guinea, Malaysia, India and Cambodia. To support breeding activities, detailed studies of flowering and seeding behaviour were undertaken (e.g. Sedgley *et al.*, 1992). Flowering and seeding commence at about two years of age under plantation conditions. Pollination is by insects, especially bees, and mature pods can be harvested about seven months after flowering. Research to develop vegetative propagation and controlled seed production technologies began first in Malaysia (Carron and Aken, 1992). This work has since gained momentum, especially in Vietnam where outstanding hybrid clones have been identified, tested and mass propagated for commercial operational use (Kha, 1996, 2001; Nghia, 2000; van Bueren, 2005).

- Propagation and Silviculture

To fully realize the benefits of the tree breeding and hybridization work an effective and economical means of mass propagation was developed. Stem cuttings of young *A. mangium* seedlings are easily rooted when they are treated with hormones and planted in suitable rooting medium. However, the rooting percentage of stem cuttings decreases significantly with older stock plants (see papers in Carron and Aken, 1992). There has been significant progress in both micropropagation and conventional root cuttings and the use of cuttings of select trees is now a common feature of commercial plantings of *A. mangium*.

Acacia mangium fixes nitrogen in many tropical soils after nodulating with a range of *Rhizobium* and *Bradyrhizobium* strains. It is, however, much more specific in its *Rhizobium* affinities than some other acacias (Dart *et al*., 1991). This nitrogen-fixing potential may only be realised in many soils if adequate P and sometimes K fertiliser is applied, but nodule development may be inhibited at higher levels of N. Inoculation with *Rhizobium* is not usually essential but may be beneficial when seedlings are raised in sterilised media or planted on highly degraded soils or mine spoil.

Pests and diseases must be considered as part of the domestication process as they can be major factors in management of plantations. Surveys of insect pests and diseases of *A. mangium* have been made. Foliar diseases stem cankers, root rots and heart rots have been identified, with root rot widespread and a potentially serious threat to plantations established on recently cut-over forest (Old *et al*., 2000; Barry, 2002; Potter *et al*, in press). There are recent reports that a root rot caused by *Ganoderma* sp. can affect 5-20% of second-rotation *A. mangium* plantations. Whilst few insect pests have been recorded, Nair and Sumardi (2000) identified the sap-sucking bug, *Helopeltis* spp. as a potentially serious threat in *A. mangium* plantations.

Domestication and Use of *Acacia crassicarpa* A.Cunn. ex Benth.

A. crassicarpa illustrates the potential for rapid domestication of fast-growing, early-flowering tropical tree species. In 1980 *A. crassicarpa* was almost of insignificant commercial importance in native forests and was best known by botanists and ecologists through its close association with its better-known cousins, *A. mangium* and *A. auriculiformis*. Over the past twenty years, it has gone from a virtually unknown tree in the wilds of north Queensland and New Guinea to a major commercial plantation species for pulp and paper in Southeast Asia. Its natural occurrence in the humid tropics, good bole form and vigour on poorly drained, acidic sites suggested it could find a place in tropical forestry.

In its natural stands, *A. crassicarpa* is a moderately large tree up to 30 m tall which reaches its best development in the south of Papua New Guinea and West Papua, Indonesia. In north Queensland it is a component of many diverse vegetation associations on a variety of soil types but in Papua New Guinea (PNG) it occurs in woodlands and open-forests commonly fringing seasonally flooded plains. It occurs frequently in mixed associations with *A. auriculiformis*, *A. mangium*, *A. leptocarpa* and species of *Melaleuca* and *Lophostemon* (Thomson, 1994; Doran and Turnbull, 1997).

It was first tested in China and Thailand in the early and mid 1980s and subsequently in neighboring countries such as Indonesia, Malaysia and Vietnam. Over 200,000 ha of commercial plantations have now been established in Sumatra, Indonesia, where it is being grown on highly organic soils with a low pH that may be waterlogged occasionally (CSIRO data; Midgley, 2000). The tree has outstanding, as yet largely untapped, potential for other very difficult sites in South-East Asia. These include planting above saline seeps in northeast Thailand for groundwater recharge control, and reforestation of acidic, infertile sands with seasonal waterlogging and shallow hardpan in central Vietnam. *A. crassicarpa* also has potential in agroforestry and is now being grown for fuelwood in woodlots by 3,000 farmers in Tabora district, Tanzania, following its introduction in 1988 by the International Centre for Research in Agroforestry (D.J. Boland, *pers. comm.*).

The rapid domestication of *A. crassicarpa* has involved substantial collaborative R&D work in Australia, Indonesia, Malaysia, Thailand, Vietnam and China. Unlike *A. mangium*, the most productive provenances were identified before large-scale planting commenced. Much of the early work was initially within projects between CSIRO and research partners supported by ACIAR, and under the auspices of the Consultative Group for Research and Development of Acacia (COGREDA), national institutes and most recently in the private pulp and paper sector.

- Sampling and Characterisation of Genetic Variation

The first seed collections of *A. crassicarpa* destined for forestry research were collected for CSIRO in north Queensland in 1981. The FAO Forestry Department and the Danish aid agency, DANIDA, shared an enthusiasm for the potential of tropical acacias for reforestation, and in 1982 supported joint CSIRO/PNG Forest Research Institute collections to complete the sampling of *A. crassicarpa* in Australia and PNG (Turnbull *et al.*, 1983). Further collections by the CSIRO Australian Tree Seed Centre followed over the next 10 years with donor support from AusAID and ACIAR (Gunn and Midgley, 1991). These included the first collections of *A. crassicarpa* in Irian Jaya, Indonesia, in 1990, in collaboration with the Indonesian Ministry of Forestry (Vercoe and McDonald, 1991).

Species/provenance trials in Thailand clearly demonstrated the outstanding growth potential of PNG provenances of *A. crassicarpa*, with early height growth rates of 5 m per year being recorded (Pinyopusarerk, 1989). Interest in *A. crassicarpa* grew rapidly once high quality, source-identified seed was available from natural provenances. By 1990, the ATSC had sent out over 500 research seedlots, primarily to research partners in South-East Asia and China. By 1993 the species had demonstrated excellent survival and vigour in trials across a range of sites in the humid tropics and was recorded by COGREDA as the third most important tropical acacia in Southeast Asia (Awang and Taylor, 1993). Its suitability for shallow sandy soils (e.g. Sim and Gan, 1991), peaty soils and the overwhelming superiority of the PNG provenances had been demonstrated (e.g. Chittachumnonk and Sirilak, 1991). However, a comparison of the various provenance trials shows there is a strong genotype x environment interaction and not all PNG provenances grow well on all sites (Awang *et al.*, 1998). Queensland provenances appear to be more resistant to cyclone damage than the faster-growing PNG provenances. Provenance variation in economically important wood properties has been demonstrated in Malaysia (Shukor *et al.*, 1998). The same study identified Samlleberr (West Papua) and Olive River (north Queensland) as the most promising seed sources for growth and wood properties for industrial plantations. Seed orchards have been established by CSIRO and research partners in Thailand, Vietnam and Philippines and by commercial companies in Indonesia.

- Breeding

The breeding system and genetic diversity were studied by Moran *et al.* (1989b). Seedling seed orchards were first established in China (Pan, 1988) and subsequently in Australia (Harwood *et al.*, 1993), Indonesia (Nirsatmanto, 1998), Philippines, Thailand and Vietnam. *A. crassicarpa* is closely related to other commercially important Acacia species (McDonald and Maslin, 2000) and there is potential for intra-specific hybrids with *A. auriculiformis*, *A. peregrina*, *A. mangium* and *A. midgleyi* to improve certain attributes or perhaps utilise heterosis for growth as observed in the *A. auriculiformis* x *A. mangium* hybrid in Vietnam.

- Propagation and Silviculture

Cuttings can be successfully rooted from trees less than three years old but are difficult to root when taken from older trees (Thomson, 1994). Marcotting is effective for vegetative propagation from older trees (Awang *et al.*,1998). Maintenance of juvenility in hedge plants is a significant challenge to development of fully-clonal planting programs.

Acacia crassicarpa is susceptible to some foliar disease and root rots but has not yet been damaged by heart rot (Old *et al.*, 2000). Insect pests such as stem borer beetles (*Platypus* spp.) and the stem-girdling beetle (*Sinoxylon* sp.) have been reported (Thomson, 1994) but so far damage by pests has been localized.

CONCLUSIONS

The tropical acacias have become an established part of the plantation landscape in many countries and are offering considerable economic, social and environmental benefits.

They have proven to be highly attractive for production of high value, short fibred pulps, and already-extensive plantations are expanding to meet market need. As acacia plantations mature and wood supplies become more reliable, industries are being established to use their high quality woods for furniture, flooring and other solid wood applications. International markets for small size acacia logs have evolved and this is matched by a market acceptance of acacia solid wood.

Their domestication so far has left an exciting foundation of knowledge upon which further challenging work can be built. The problems experienced with weediness and serious genetic deterioration due to inbreeding when introduced and managed haphazardly have been recognised and are the focus of attention. The current rapid planting of tropical acacias has been similar to that of eucalypts in South America in the 1970s. The ongoing advances witnessed with eucalypts in South Africa are likely to be repeated with acacias in SE Asia – productivity will increase, industrial benefits will accrue and environmental and social issues will be more closely understood.

The tropical acacias have become an established part of the commercial plantation industry in SE Asia. Their rapid domestication and commercialization in less than 40 years has been remarkable and rivals that for any other plant species. Knowledge of natural variation, breeding systems, silviculture, propagation, fungal pathogens and insect predators, wood quality and the emergence of molecular technologies promise much for the future development of these species. International collaboration has contributed greatly to the domestication process so far and will continue to be important.

Domestication is not simply selection, breeding and attaining higher productivity. Productivity must be attained within the principles of sustainable plantation forestry upon which the sustainable business of plantation forestry rests. Acacias are a preferred source for high quality fibre for many modern pulp and paper industries. Provided the principles of sustainable plantation management are respected, acacia plantations offer an economically, socially and environmentally attractive option for supply of high quality raw material.

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