Acacias for Rural, Industrial, and Environmental Development

Proceedings of the second meeting of the Consultative Group for Research and Development of Acacias (COGREDA) held in Udorn Thani, Thailand, February 15-18, 1993

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edited by
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Cover: (top) *Acacia mangium* seedlings in a nursery for industrial plantation in South Kalimantan, Indonesia; (middle) a woman in Lampang, northern Thailand, cuts *A. catechu* into pieces for extracting *kutch* in a cottage industry process; (bottom) an *A. mangium* plantation reclaims grasslands formerly dominated by weedy *Imperata cylindrica* in Kota Belud, Sabah, Malaysia. Photos: Enso Forest Development, Co., Ltd.; Wanida Subsansenee; and Kamis Awang.

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Introduction

Acacia species, many of which are native to Australia and Asia, have shown fast growth on a wide range of sites and have various uses. The Consultative Group for Research and Development of Acacias (COGREDA) was formed to provide a means for researchers working on various aspects of acacias to exchange information, assess research to date and future directions, and plan ways of filling knowledge gaps. Comprised primarily of Asian scientists, the Group emerged from a recommendation by the Multipurpose Tree Species Research Network of the Forestry/Fuelwood Research and Development (F/FRED) Project.

The first COGREDA meeting in June 1992 prioritized research needs for: species assessment and improvement; silviculture for industrial, agroforestry for rural development, and site reclamation purposes; utilization; and economic assessment (see Appendix 1 for summary). It also finalized tasks for producing a monograph on *Acacia mangium*, to be published by F/FRED in the coming months. F/FRED is also supporting several of the research proposals identified at the first meeting.

The Group's second meeting, in Udon Thani, Thailand, February 15-18, 1993, examined more closely the contribution of acacias to the three broad areas of rural, industrial, and environmental development. Specifically, it reviewed the extent to which acacias are being used in the Asia-Pacific region for these purposes, identified relevant research needs, and planned for further synthesis of results on several of the most researched species. The meeting included greater representation of countries growing acacias in semi-arid and arid environments, and the Group welcomed broader participation in the course of its growth.

In sponsoring this meeting, F/FRED was joined by the ASEAN-Canada Forest Tree Seed Centre in Thailand, the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), the FAO Forestry Research Support Program for Asia-Pacific (FORSPA) and Forest Tree Improvement Project (FORTIP), and the Finnish International Development Agency.

This range of co-sponsorship suggests the potential for COGREDA to continue in its role of assessing research progress from several end-user perspectives, synthesizing the results, and coordinating regional research initiatives. At the meeting in Udon Thani, the Group members endorsed the proprosal that this might best be achieved through affiliation as a working group of the International Union of Forestry Research Organizations (IUFRO).

The meeting organizers would like to thank the Udorn Thani Provincial Forest Office, particularly Mr. Sanan Siriwattanakarn and Mr. Prayuth Saipankaew, for their hospitality. The editors thank the F/FRED staff members Ms. Sopapan Varasarin, Ms. Apinya Chaivatanasirikul, and Ms. Leela Wuttikraibundit for their assistance.

Meeting Summary and Recommendations

The Group's discussions started from the baseline of species assessment and improvement, silviculture, and utilization research and priorities identified at the first COGREDA meeting in June 1992 (see appendix for summary).

The second meeting pursued these with a more in-depth view of the role that acacias can play in Asia. Rural, industrial, and environmental development will all be increasingly important in Asia-Pacific countries as

- rural populations continue to grow and face problems of poverty and inadequate resources. Failure to address their needs for tree products and livelihood can lead to destabilization of the natural resource base, not to mention further deterioration in their living standard.

- economic growth in these countries depends on the ability of governments to encourage sustainable industrial growth to meet the increasing international market demand for tree products.

- environmental sustainability, already much at risk, will be important in maintaining long-term benefits from the first two areas, as well as in responding to increasing internal and external pressure for an "environment-friendly" forest industry.

These three catgories provide a useful framework for the following discussion. The factors are inter-related, however, and research addressing them should recognize this with an integrated approach that suits the end-use objectives.

The assessment of national problems and priorities below is offered as a step toward identifying overlapping areas for regional collaboration.

The Group recognizes that some of the recommendations below are ambitious, but in viewing past efforts sees some use in setting such goals, as they provide guideposts for long-term objectives, even if they cannot be met with the Group on its own.

Acacias in Rural Development

Discussion leader: H.A. Francisco
Rapporteur: B.S. Nadagoudar

This discussion provides general indications as assessed by the group; more detailed and serious consideration of priorities for rural development will of course need to proceed on a more site-specific basis, in consultation with farm communities.

Policies affecting tree-planting by rural communities

Many countries in the Asia-Pacific region already have national policies that encourage tree planting by communities. While these have been put into practice through a variety of community forestry, social forestry, and agroforestry programs, there remains a lack of adequate legislative measures that provide farm communities with adequate land and tree tenure to ensure their greater involvement in tree planting.

In some countries, the government has given this issue serious consideration and has partially solved land and tenure problems. However, there is now an urgent need for national governments to re-examine these policies, as farm forestry and agroforestry will assume greater importance in the years to come.

Status of acacia planting in farm communities

The most common of the many systems and intended uses for planting acacias in the Asia-Pacific region are:

- homestead trees
- other agroforestry systems
- farm woodlots
- fodder plantings
- wasteland development plantings
- river, streambank, and roadside plantings
- aesthetic and home environment enhancement
- medicinal purposes
- non-wood products and uses

Promising acacias for rural development (with strike rates as a rough gauge of their relative regional importance) are:

Acacia auriculiformis	37
A. mangium	36
A. crassicarpa	31
A. aulacocarpa	30
A. leptocarpa	28
A. holosericea	21
A. cincinnata	15
A. catechu	13
A. mearnsii	6
A. senegal	6
A. nilotica	6
A. tortilis	4
A. leucophloea	4
A. planiformis	4
A. insuavis	4
A. confusa	1

Potential systems for acacia planting are reviewed in Table 1.

While there is economic data available on industrial planting, gauging the socioeconomic contribution of tree planting to local communities is still difficult for any tree genus. The framework proposed in the paper by H.A. Francisco, using the criteria of (1) contribution to local income generation, (2) contribution to greater equity, and (3) contribution to the environment for sustainable economic benefits, could be refined for this purpose. Table 2 offers an estimate of the current contribution of acacias to rural development in each country.

Table 1. Potential planting systems involving acacias, by country.

System	India	Ind'sia	Laos	Mal.	Myan.	Nepal	Pak	PNG	Phil.	ROC	S. L.	Thai.	Viet
Agroforestry													
living fences	3	1	2	0	1	2	2	2	1	0	1	1	1
hedges	3	1	0	0	1	2	2	1	1	0	1	1	1
windbreaks	1	1	0	1	1	2	2	0	1	1	2	1	2
alley cropping	0	2	1	0	0	1	0	3	1	0	1	1	2
wide row intercrop	0	2	1	1	1	2	1	1	1	1	2	2	2
shade/nurse trees	0	2	1	1	0	2	1	3	2	0	2	1	2
support trees	0	2	0	1	0	1	1	0	1	0	1	1	1
homegardens	0	2	2	1	1	3	1	3	1	0	1	1	2
ornamentals	0	1	2	3	1	2	1	1	2	3	1	2	1
taungya	0	2	1	1	2	3	0	0	1	0	0	1	0
fodder banks	2	0	0	0	1	3	3	0	0	0	0	0	0
pasture improv.	3	0	0	0	1	3	2	1	0	0	0	0	1
agrisilvipastoral	2	0	2	0	0	3	2	1	1	0	0	1	1
Soil conservation	2	2	1	3	1	3	2	2	1	2	2	2	2
Soil fertility improvement	2	3	3	1	1	3	2	2	1	1	2	1	3
Community plantations	2	2	0	1	0	3	2	2	2	1	2	2	2
Industrial plantations	3	3	1	3	1	3	3	1	2	2	2	2	3
Private plantations	2	1	0	3	0	3	2	3	2	2	2	2	2

0 = no significance; 1 = low potential; 2 = medium potential; 3 = important.

Table 2. Estimated current status of socioeconomic contribution of acacia planting in rural communities.

Criteria	India	Ind'sia	Laos	Mal.	Myan.	Nepal	Pak	PNG	Phil.	ROC	S. L.	Thai.	Viet
Employment generated from industrial plantations	H	H	L	H	L	L	M	H	L	I	M	L	L
Income generation													
sale of tree products	M	H	M	M	M	L	M	L	I	I	I	I	M
processing of acacia food prod.	L	M	I	L	L	0	I	L	I	I	I	I	I
Subsistence production													
energy products (fuelwood, charcoal)	L	H	L	L	L	L	H	H	L	I	L	L	L
non-wood products	H	M	-	L	L	0	M	M	I	I	I	I	L
Medium for equity enhancement	L	M	M	L	L	I	M	L	L	I	L	I	I
Enviromental value													
soil enrichment in agroforestry	M	M	M	M	L	I	M	H	M	I	M	L	M
soil conservation/ erosion control	M	M	M	M	M	I	M	I	M	H	M	L	M
Shade and aesthetic value	M	L	L	H	M	I	M	I	L	H	L	L	L

0 = none; I = insignificant; L = low; M = medium; H = high

Acacias for fuelwood and charcoal

The importance of fuelwood and charcoal is clear from the fact that about 80% of total wood used in the region goes to these products. Table 3 suggests *Acacia* species for these uses, by country (see also the paper by Yantasath et al.).

Non-wood products and uses

High-value, non-wood products and uses can play a large role in farmer adoption of tree-growing technologies (see the paper by H.H. Chung). Their importance should be recognized through:

- technology improvement or development for high value-added gains (see the paper by Wanida Subansenee et al.)
- government-provided incentives for establishing local, small-scale processing centers
- facilitation of marketing of these non-wood products by government and/or non-government organizations

Table 4 indicates the status of non-wood product and use potentials for acacias in each country.

Research and development priorities

Table 5 suggests priority topics for research and development of acacias aimed at meeting needs of rural populations.

Promoting tree-growing options in communities

Research and exploration of community interest in tree-planting concerns should go hand in hand. Table 6 suggests promising ways for making tree-farming options available and adaptable to communities.

Table 3. Potential fuelwood and charcoal species, by country.

Species	India	Ind'sia	Laos	Mal.	Myan.	Nepal	Pak	PNG	Phil.	ROC	S. L.	Thai.	Viet
Humid/Subhumid													
A. auriculiformis	1	2	1	2	2	3	1	2	3	0	3	3	3
A. mangium	0	2	1	1	2	1	0	2	1	0	1	1	2
A. aulacocarpa	0	0	1	0	0	0	0	0	2	0	2	1	2
A. crassicarpa	0	0	1	0	0	3	0	0	2	0	2	1	2
A. tomentosa	0	0	1	0	0	0	0	0	0	0	0	1	0
Semi-arid													
A. nilotica	3	0	0	0	0	3	3	0	0	0	0	0	0
A. catechu	2	0	2	0	2	3	1	0	0	0	0	2	0
A. holosericea	1	0	1	0	1	2	0	0	1	0	2	0	2
A. senegal	3	0	0	0	0	0	0	0	0	0	1	0	0

0 = no significance; 1 = low potential; 2 = medium potential; 3 = important.

Table 4. Indication of importance of non-wood products and uses,* by country.

Product	India	Indonesia	Laos	Mal.ay.	Myanmar	Nepal	Pak.	Philipp.	ROC	S. Lanka	Thai.	Viet.
Bee honey	2	1	1	2	1	0	2	0	0	1	1	0
Chemicals**	3	2	3	1	0	2	1	0	0	0	1	1
Fodder	3	1	0	0	1	3	3	0	0	0	0	0
Food	0	0	0	0	0	1	1	0	0	0	1	0
Handicrafts	2	1	0	1	1	1	2	1	0	1	1	0
Others	3	1	1	1	1	1	0	1	0	0	1	1

*excluding charcoal and fuelwood
**including gum arabic, tannin, extractives, etc.
0 = no significance; 1 = low potential; 2 = medium potential; 3 = important.

Table 5. Research and development priorities for meeting needs of rural populations.

Goals	R&D Topic	Activity
Maintain biodiversity of acacias	Explore indigenous acacias through involvement of local communities	Identify seed origin and seed sources
	Conduct on-farm trials of native and exotic acacias with other promising MPTS (species cum provenance trials)	Select suitable species and provenances based on site qualities and local preferences
Develop systems for breeding	Study flowering and seed crop of native and exotic acacias	Collect good seeds in sufficient amounts to meet rural demand
Mass produce planting materials	Explore suitable propagation techniques	Produce sufficient good-quality planting stock for rural demand
Refine suitable planting systems	Refine agroforestry systems involving acacias	Conduct site-specific research to meet local needs
Maximize wood and non-wood production according to demand	Investigate intensive management practices according to desired products and techniques	Determine sound silvicultural practices and control of biotic and abiotic pests
Maintain sustainable production systems	Examine the cost-effectiveness of rhizobium inoculation and long-term nutrient cycling	Develop suitable selection, growing, and inoculation methods
Promote acacia-growing options as alternatives to shifting cultivation	Conduct feasibility studies of incentive programs for government and international agency support	
	Develop appropriate technology transfer and monitoring programs	
Promote tree-growing on degraded forests, community lands for fuel-wood, charcoal and other products	Identify germplasm adapted to extreme site requirements and adoptable management regimes	
	Adapt methods for suitable technology transfer	
Increase contribution of acacias to rural household income	Quantify and evaluate economic uses in rural communities	
	Assess market potentials of wood and non-wood products	
	Develop non-wood uses with significant market potential	
	Develop/upgrade processing techniques	
	Study the effects of policies on production and marketing of specific products	
Increase participation by local communities in tree growing	Examine ways to facilitate NGOs and government agencies in working constructively with communities	
	Examine policy measures for promoting NGO work in tree growing	
Promote tree cultivation on wastelands for environmental amelioration (of grasslands, tin tailings, etc.)	Quantify and value benefits from soil amelioration by trees	
	Provide economic and tenure incentives for tree-growing in these areas	
	Establish demonstration tree farms for technology adaptation and transfer	
	Distribute planting materials through government agencies and NGOs	

Table 6. Means for promoting tree-farming options in farm communities, by counry.

	Ind.	Ind'sia	Laos	Mal.	Myan.	Nepal	Pak	Phil.	PNG	ROC	S. L.	Thai.	Viet
Policy incentives													
subsidies (e.g., seedlings)	3	3	3	0	1	3	3	3	3	3	3	3	3
low-cost credit	3	3	3	0	0	3	3	3	3	3	3	3	3
secure tree tenure	3	1	2	0	0	2	2	3	0	0	2	1	1
land tenure	1	3	3	3	1	2	2	3	0	0	2	2	2
tax incentives	2	0	2	2	0	2	1	1	1	1	1	1	2
Marketing support													
R&D support for product development	3	2	2	2	1	3	2	3	3	1	2	3	2
Price information support	3	1	1	2	1	3	1	3	3	1	1	1	1
Empowerment of communities													
cooperative system/	2		2	2			1			1		2	
social organization		2			1	3		3	1		2		2
training	3	3	2	2	1	2	3	3	2	1	3	3	3
Technology transfer													
nurseries	2	1	2	2	1	3	3	2	3	0	2	2	1
soil management	2	2	2	0	1	3	3	-	3	1	2	3	2
seed procurement	3	2	1	3	1	3	2	3	0	0	2	2	2
logistical support	3	2	2	2	0	2	2	3	2	1	2	2	2
extension	2	3	2	2	1	3	3	3	3	3	3	3	3

0 = no significance; 1 = low potential; 2 = medium potential; 3 = important.

Acacias in Industrial Development

Discussion leader: Chin Y. Wong
Rapporteur: Sompetch Mungkorndin

As natural forests in the region disappear and utilization technologies adapt to small-diameter logs from plantations, fast-growing acacias are playing a growing role in supplying large-scale export demand. In the Asia-Pacific region, this is particularly true in Indonesia, Malaysia, and Thailand.

Current level of plantation forestry using acacias

The Indonesian government has set a target of 6.2 million ha of industrial plantation by the year 2000; this is independent of private industrial planting already ongoing at a rate approaching 20,000 ha per year in Sumatra. *A. mangium* is a priority species in both cases. For Sabah, Malaysia, the planting targets of the three major plantation organizations (including a heavy reliance on *Acacia mangium*) total 260,000-310,000 ha. Thailand is also encouraging plantations, although policy clarification is needed; its current target is for 15% of the land area to be 'economic forests' of fast-growing species, including *A. mangium.* Laos and Vietnam are also now entering into large-scale plantation forestry using acacias. In Australia, however, industrial plantations consist primarily of eucalypts, not acacias.

Product development and marketing

In Indonesia, primary industrial products from acacias are pulp, paper, and rayon, building material, furniture, and fuel. Laboratories in Malaysia are drawing on the experience of the rubber industry and technological advances in processing small-diameter logs to develop a range of composite products that meet international standards. The industry is exploring new products with its current markets and new export markets in the Middle East and elsewhere.

The Australian Tree Seed Centre makes available seeds from natural stands of acacias to research and development efforts, and has set up seed production areas of several acacias to meet the growing demand and to start genetic improvement. Similar seed production areas have been set up in Indonesia, Malaysia, and Thailand to produce seeds for sale locally and export.

Non-wood products also represent important and potentially important industries; for example, gum arabic tapped from acacias for pharmaceutical and other industrial uses. The uses of *A. catechu* extractives for tannin, dye, and as a traditional after-meal digestive in South Asian countries contribute to several important cottage- and large-scale industries.

Local socioeconomic impact

Countries differ in their emphasis of this aspect relative to site reclamation and other objectives. In Indonesia, both government and private sectors are putting a major effort to rehabilitate grasslands infested by the weed *Imperata cylindrica*; this provides employment opportunities directly or indirectly to local people. In Sabah, Malaysia and the Philippines, the concept of tree farming has been introduced to farmers near pulp and paper mills. Farmers are encouraged to grow trees through free distribution of seedlings and/or guaranteed purchase of their harvest. On the other hand, the Sabah Forest Development Authority's project for wasteland rehabilitation uses the "forest village" concept to involve local inhabitants.

Species and provenance trials

The main acacias currently evaluated for block plantation in both humid/subhumid and arid/semi-arid areas of Asia-Pacific are: *A. mangium, A. auriculiformis, A. crassicarpa, A. aulacocarpa, A. cincinnata, A. mearnsii, A. holosericea, A. polystachya, A. melanoxylon, A. leptocarpa, A. difficilis, A. flavescens* and *A. shirleyi*.. The humid/subhumid species are being studied mainly in Southeast Asia and the Pacific; the semi-arid acacias are mainly evaluated in South Asia and drier parts of Myanmar and Thailand.

So far, most trials by private industry have focussed on *A. mangium*. Companies in Sumatra, Indonesia have identified good provenances from Papua New Guinea, Queensland Cape York (Australia), Irian Jaya (Indonesia), and Sabah. The other principal acacias being tested are *A. crassicarpa, A. auriculiformis, A. aulacocarpa,* and *A. cincinnata*. The Indonesian government has sponsored trials of these species at various sites in its national network since 1981, as well as of *A. silver, A. oraria,* and *A. leptocarpa*. Plus tree selection and half-sib progeny tests are underway there.

In Malaysia, the Forestry Departments and private industry are conducting species and provenance trials of *A. mangium, A. auriculiformis, A. crassicarpa, A. aulococarpa,* and *A. cincinnata*.

In Thailand, government agencies and private industry have been evaluating more than 25 species, and as many provenances of some of those species, for more than 10 years.

Myanmar, Laos, and Vietnam have begun species and provenance trials of *A. mangium, A. auriculiformis* and other acacias more recently.

Provenance testing of the semi-arid acacias are comparatively less extensive, although various varieties of *A. nilotica* are well known.

Growth and yield

Research on growth and yield has been conducted in most countries. Volume tables for *A. mangium* and *A. auriculiformis* have been developed in Indonesia, Malaysia, and Thailand. The MAI for volume of acacia in Indonesia and Malaysia is about 15 m^3 and 20 m^3 respectively.

Intensive management practices

Practices vary by country. In Australia, plantation management includes mechanical site preparation, fertilizer application, and chemical weeding. On the other hand, minimal stand management is practiced in Myanmar and Thailand due to the relatively small scale of the plantations.

In the large plantations in Indonesia and Malaysia, provenances with many seed parents are commonly used, and block plantings include a number of species to prevent rapid spread of pests and diseases. Where a species is grown in monoculture, a broad range of provenances is selected and the plantation is bounded by natural forest reserves for the same purpose. Circle weeding and inter-row slashing are usually done manually, and thinning, pruning, and singling are practiced depending on the end product. *Imperata* sites demand intensive weed control, although the return on investment is lower than on better sites, at least at first. Fire control measures are practiced in the dry season.

Agroforestry practices

Intercropping of acacias with other cash crops is being practiced in several countries (for example, with *A. mearnsii, A. mangium* and *A. auriculiformis* in Indonesia, and *A. mangium* in Malaysia).

Biotechnological research

Clonal forestry of acacias will play a growing role in plantation forestry in the coming years. The potential contribution of tissue culture is not yet clear for lack of field tests of tissue-cultured plantlets vs. seedlings. Table 7 shows biotechnological research, by certain countries.

Policies affecting industrial planting

Policies vary by country. Indonesia and Malaysia both have strong government plantation programs that rely heavily on *Acacia mangium* for meeting future demand. Indonesia is supporting this through a large program of tree improvement research. The Malaysian government provides plantations with (1) tax incentives, (2) long-term leases with sliding-scale rent rates until plantation establishment, and (3) incentives for research and development. In Thailand, while certain incentives are helping, a clearer land rights policy is needed, and fewer bureaucratic obstacles to harvesting of exotic species. A number of countries like Laos and the Philippines now make available areas for replanting to either communities or large-scale growers through long-term leases.

Table 7. Biotechnological research by four countries in the region.

Research area	Australia	Indonesia	Malaysia	Thailand
Micropropagation				
A. mangium	x	x	x	x
A. auriculiformis		x	x	x
natural hybrid		x	x	
Isozyme studies	x	x	x	
Chromosome studies	x		x	
Molecular biology (*A. melanoxylon*)	x			

Incentives

Most national governments offer incentives for plantations. In Indonesia, a levy of US$10 is collected from every cubic meter of mixed tropical hardwood harvested for reforestation purposes. This fund (US$1,000/ha) is distributed to reforestation projects over a three-year period.

Malaysia offers four general incentives: (1) no land tariff is applied to reforestation projects; (2) an industry's development costs are not subject to taxation during the first five years; (3) land is leased at a low fee; and (4) a royalty is imposed on exports of mixed tropical hardwoods that generally come from natural stands.

Thailand also provides a low leasing rate. However, in response to pressure from communities and NGOs, the government in 1991 suspended granting concessions for industrial plantations.

Research and development constraints and needs

Scarce funding for research is a perennial constraint in the private sector, as is availability of germplasm for planting and improvement. Further seed collections of acacias are needed from less-tested natural sources, including sources in Irian Jaya. Field performance of trees from stem cuttings and hybrids require further evaluation. Nutrition studies are needed to assess the ability of acacias to reclaim degraded sites (for example, *Imperata* grasslands) for cultivation of higher-value species.

In countries like Indonesia and Malaysia, many government and private sector agencies are involved in forestry research. In such cases the need is for coordination. In countries like Myanmar, on the other hand, trained and experienced researchers are in short supply and there is an urgent need for more technical cooperation from other countries. In between these two extremes are countries like Thailand, where researchers have made good progress in narrowing the choice of species to suit the country's various site conditions. In such a situation the constraint is lack of funds and support for further large-scale field tests and pilot plantations.

Acacias and the Environment

Discussion leader: P. Srivastava
Rapporteur: Su See Lee

In view of the large effort already invested in research and establishment of acacias in the Asia-Pacific region, it is timely to consider their impact on the environment. As noted in the paper by Reynaldo dela Cruz, the role of acacias in the environment might be considered in terms of their effects on:

- the soil (erosion control, conservation of microflora, nutrient storage and cycling)
- water resources
- conservation of carbon dioxide (the trees' role as carbon sink)
- microclimate amelioration

Table 8 shows the Group's recommended priorities for environmental studies under the COGREDA umbrella. While many acacias hold multiple benefits to growers, there are also adverse effects associated with planting acacias, as with any activity. The research priorities are therefore grouped according to

Table 8. Priority research topics for determining the environmental effects of acacias.

Potential Beneficial Environmental Effects	Potential Adverse Effects
Rehabilitation of catchment areas	Site degradation due to site preparation for plantations
Soil conservation and erosion control	Adverse changes in the water table (arid/semi-arid areas)
Improved fallow in shifting cultivation	Effects on human and animal health (e.g., pollen allergies)
Nutrient cycling (storage and release), and development of soil micro-organism populations	Reduced biodiversity on ex-forest sites
Site reclamation for: acid sulphate soils, saline-alkaline soils, grasslands, sand dune stabilization, windbreaks and firebreaks, mine spoils and tin tailings, shallow sites, nurse crop for more-demanding species	Effects of native vs. exotic acacias
Urban plantings (roadsides, housing estates, sound screening, shade, live fences)	Effects of monospecific plantations compared with mixed-species plantings
Role as carbon sink	Potential danger of weediness
Positive effects on the water table (humid areas)	Allelopathic effects (for example, with wheat)
Amelioration of microclimate	

beneficial and adverse environmental effects. The topics are not ranked as to priority, as priorities will vary from country to country and information on this variation is not yet available. It was felt that the studies would result in more open examination of options by not listing them in relation to specific technologies, such as agroforestry.

Finally, all acacia planting projects involving more than 1,000 ha of plantation should be preceded by a formal, written environmental and social impact assessment. Some countries in the region already require this (for example, Thailand (for more than 200 ha) and Malaysia (for 500 ha and more).

Future COGREDA Activities

Following the trend of the first two COGREDA meetings, the Group looks forward to broader participation by geographic regions. The Group emphasizes the need to distinguish between national and regional problems, as at this meeting: national problems must be assessed first before shared problems and areas of interest can be identified for regional or sub-regional collaboration.

One option for long-term continuity, already approved by the Steering Committee of the MPTS Research Network, is affiliation of the group with IUFRO as a working group. This proposal was welcomed by the Group. Over the long term, the group expressed interest in four types of activities. The first three are:

further working meetings
Future meetings could involve sub-groups on more specialized topics, such as quantitative genetics, silviculture, and utilization.

monographs
Further monographs would bring together the wide range of acacia research on given topics. Three species monographs were proposed on *A. auriculiformis*, *A. nilotica*, and *A. catechu*.

collaborative regional research
Proposals on a range of technical and socioeconomic topics could be considered and funded, depending on funding support received. Four areas that might be supported by the FAO Forestry Tree Improvement Project (FORTIP) are:

- seed exploration, collection, and distribution of *A. mangium* and *A. auriculiformis* and provenance and progeny trials of *A. crassicarpa*
- establishment of a regional seed orchard program
- promotion of research and development of hybrids
- promotion of clonal forestry using proven species and their hybrids

The fourth activity suggested was to organize a meeting with donor agencies to gauge their interests in funding various COGREDA initiatives.

The venue of the next meeting was proposed to be either Indonesia or Australia in February 1994.

Acacias for Rural, Industrial, and Environmental Development in Southern China

Zheng Haishui and Yang Zengjiang

Introduction

The area of Southern China (below latitude 23.5°N) covers about 480,000 km². Annual mean temperature is 20°C (maximum 38° C, minimum 5°C); annual rainfall is about 1,500 mm mainly occurring in the rainy season from March to July on the mainland, and June to October on Hainan Island. Typhoons occur frequently from August to September, and the overuse of land, particularly deforestation, has caused serious soil erosion and ecological degradation. Depletion of forest resources has caused shortages of timber, firewood, forage, and green manure.

Some acacias are native to Southern China but only *Acacia confusa* is suitable for poor sites. Since the 1960s, about 100 tree species of *Acacia* have been introduced into Southern China from Australia and Papua New Guinea, and species elimination and provenance trials have been established in Guangdong, Hainan, Guangxi, Fujian, and Yunnan provinces.

A. auriculiformis was first introduced into the Botanic Garden of Southern China in 1961. Experimental plantations were established in the Guangdong Forestry Institute and Zhaoqing Forestry Experiment Station in 1964. Its good performance has attracted attention of the local people and forestry workers and as a result, *A. auriculiformis* has been widely used in reforestation programs since the 1970s.

At the same time, 80 other *Acacia* species began to be introduced, including *A. mangium, A. cincinnata, A. aulacocarpa, A. crassicarpa, A. consurrens*, and *A. mearnsii. A. auriculiformis, A. mangium, A. cincinnata, A. cunninghamii, A. mearnsii*, and *A. dealbata* emerged successfully from elimination trials, showing high adaptability, fast growth, high yields, and multiple uses. *A. auriculiformis, A. mangium, A. cunninghamii*, and *A. holosericea* have been planted on a large scale, now covering about 60,000-70,000 ha. Other acacias are under study.

Initially, acacias were introduced as ornamental or greening species for planting around houses and along roadsides and riverbanks. Later they came to be used as water and soil conservation forests, for fuelwood and timber plantations, or in mixed plantings as shelterbelts. Gradually the people in the region have become familiar with acacias' characteristics.

Acacias for Rural Development

Growth Performance

Growth performance of the more than 100 introduced *Acacia* species is, of course, quite variable in Southern China. In general, however, the mean annual increment (MAI) of the superior species or provenances is about 2-3.5 cm in DBH, 1.8-3.8 m in tree height, and 20-30 tons in biomass per ha. Tables 1-4

Table 1. Growth performance of some acacias in Hainan province.

Species	Age (y)	Survival (%)	DBH (cm)	Height (m)	Volume (m/ha)	Biomass (t/ha)
A. cunninghamii	5	72.5	8.49	10.87	93.81	99.16
A. auriculiformis	5	74.3	8.63	11.83	91.89	110.20
A. mangium	5	57.5	11.13	10.68	101.36	107.83
A. concurrens	5	43.8	8.46	8.59	44.33	51.22

Table 2. Comparison of growth for five acacias at different sites, at 4 years of age.

	Tree height (m)				DBH (cm)			
	Suixi county*		Qionghai county**		Suixi		Qionghai	
Species	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
A. auriculiformis	4.28	4.82	8.20	8.60	4.37	5.11	7.33	8.60
A. crassicarpa	6.18	6.57	9.78	10.70	6.10	6.37	9.92	10.80
A. aulacocarpa	3.85	5.11	5.60	7.80	3.41	5.00	5.51	8.17
A. leptocarpa	4.03	5.90	7.85	8.20	4.04	4.07	7.50	7.60
A. cincinnata	2.25	2.74	4.65	4.90	1.81	2.33	3.26	3.50

*Guangdong Province **Hainan province

show the growth performance of some acacias.

Acacias for Agroforestry

Introduction of acacias has been successful but it is still early and stands are still young; the growing habits of the trees are not yet fully understood and techniques for utilization are still being developed. The major uses of acacias in the countryside are as fuelwood, farm tools, fertilizer, and honey.

Fuelwood and timber for farm tools

Fuelwood can be obtained from acacias in three years, and farm tool timber in five years after planting. Trees of larger diameter can be used as poles; smaller trees can be used as live fences and small stick; topwood and the branches are used for firing lime, brick, tile, pottery, and chinaware, and as fuel for tea manufacture.

Fertilizer

A. auriculiformis leaves in particular are rich in nitrogen and are used as green manure by the people of Southern China. Where used in fields with rice and sweet potato, the leaves enhanced crop yields by 8-10% and 20%, respectively. In planting *Pinus elliottii* plantations, the leaves were used as a

Table 3. Growth performance at 4 years of *Acacia* mixed with *Eucalyptus* in Hainan Island.

Species	Treat-ment	No.of Plants/ha	Survival (%)	Mean D (cm)	Mean Ht. (m)	Biomass(t/ha) Fuelwood (pole, branch)	Total	Volume (m/ha)
A	AxC	3333	70.5	6.22	11.03	24.37	32.1	49.17
C		3333	94.5	6.35	9.80	48.40	60.5	75.53
A	2AxC	4444	67.0	5.34	9.67	22.52	29.1	43.18
C		2222	95.6	6.65	9.61	36.34	46.1	53.94
B	BxC	3333	66.4	5.99	9.97	18.36	24.8	32.89
C		3333	92.4	6.10	9.65	36.66	48.5	61.44
B	2BxC	4444	73.3	5.21	9.28	22.49	30.3	38.56
C		2222	92.4	6.27	9.28	24.20	32.5	40.60

A = *Eucalyptus leizhou* No.1. B = *E. exserta* C = *Acacia auriculiformis*. *Source: Forest Research* 1(6):572.

Table 4. Biomass of *Acacia* mixed with *Eucalyptus* and its components, at 4 years.

Species	Treat-ment	Total biomass	Stem kg/ha	Stem %	Branch kg/ha	Branch %	Leaf kg/ha	Leaf %	Root kg/ha	Root %
A	AxC	32064.0	22671.3	70.7	1699.5	5.3	2509.7	7.8	5183.5	16.2
C		60534.2	38144.8	63.0	10253.4	16.9	3079.0	5.1	9057.0	15.0
A	2AxC	29063.4	19910.1	68.5	2607.0	9.0	1935.6	6.7	4610.7	15.8
C		46144.6	27242.1	59.1	9100.2	19.7	3440.7	7.5	6331.6	13.7
B	BxC	24801.9	17053.9	68.7	1310.6	5.3	1436.7	5.8	5000.7	20.2
C		48485.0	31031.4	64.0	5633.1	11.6	3796.2	7.8	8024.3	16.6
B	2BxC	29965.6	19996.9	66.7	2492.6	8.3	1715.7	5.7	5760.4	19.3
C		32458.3	20505.0	63.2	3690.2	11.4	3308.5	10.2	4954.6	15.3

A = *Eucalyptus leizhou* No.1. B = *E. exserta* C = *Acacia auriculiformis*. *Source: Forest Research* 4(5):546

Table 5. Principal acacias used for environmental functions in southern China.

Species	Soil improvement	Shade	Windbreak	Erosion control	Aesthetic value
A. auriculiformis	x		x	x	x
A. confusa	x	x	x	x	x
A. cunninghamii	x		x		
A. holosericea				x	
A. mangium	x				x
A. podalyrifolia					x

basic manure, and resulted in 30% greater tree height than control one year after planting.

Honey

Acacia flowers are very good honey sources. Development of bee culture is increasing but the area planted to acacias is still too small and scattered for large-scale honey production.

Industrial Development

A. mangium and *A. holosericea* now occupy about 50,000 ha as fuelwood plantations, timber stands, and mixed forest. Wood processing and timber utilization of *A. auriculiformis* are still being studied. Techniques for making pulp with *A. auriculiformis* and *A. mangium* have been successfully developed, but such utilization is so far restricted by the limited availability of harvestable timber. Most of the timber at present is used for fuelwood, farm tools, and furniture.

A. mearnsii has bark rich in tannin and is now widely planted as a resource for tannin extract in Jiangxi, Zhejiang, Fujian, and Yunnan provinces. Some factories have been built for tannin extraction in the center of the production area.

A confusa has been widely planted in fuelwood plantations; its timber is extensively used for farm tools, furniture, and house building.

Environmental Functions

Table 5 shows the main species used in southern China for environmental functions and their niches.

Soil and Water Conservation

Because of the abundant rainfall in Southern China, once the forest cover was destroyed severe soil erosion occurred immediately. For soil and water conservation in uplands, about 20,000 ha of *A. auriculiformis* and *A. holosericea* have been planted, as well as *A. confusa*. In many places erosion has been reduced by 20-30%, and in Wuhua county of Guangdong province, where water and soil erosion was most severe, planting of acacias reduced water and soil losses by more than 50%.

Windbreaks and Shelterbelts

In coastal areas subject to typhoons, acacias have been mix-planted with *Casuarina* by state farms and local farmers as protective forest belt for the protection of farmland and the rubber tree plantation. According to one study, these shelter belts have reduced windthrow and windbreak of rubber trees by 5-10%, saving more than five million yuan Renminib (RMB)(1RMB = US$0.17). In late winter and early spring, the shelterbelts also help to protect crops from cold damage and can increase yields of rice (by 10%), rubber (by 10-20%), and fruit trees (10%).

Aesthetic Value

People in southern China consider that *A. auriculiformis, A. mangium, A. confusa* and *A. podalyriifolia* have beautiful tree shapes and dense crowns. They are fond of planting such trees in their courtyards or along the sides of their homes, along roadsides and around the villages. They not only beautify the environment but also provide shade for people and livestock.

Shade

In Southern China, *A. confusa* was used as a shade tree in tea gardens. Other acacias also provide a fine environment for growing tea. On Hainan Island, many people build their cattle shelters under the crown of acacia plantations.

Soil Fertility Improvement

In Southern China, extensive land use, especially on hillv land and steep slopes, resulted in severe soil and water losses. Soils became very poor. According to one investigation, species of *Acacia* can provide up to 5-10 tons of forest litter per annum. Acacia leaves are rich in nutrition (Table 6) and decompose quickly, and the roots nodulate with symbiotic soil bacteria that can fix nitrogen from the atmosphere and increase soil fertility. Observations of *Acacia* plantations show that after three years the topsoii color and texture have begun to improve. The change of soil in different age of stand is shown in Table 7.

Table 6. Nutrient content (%) of litter in *A. auriculiformis* and *A. mangium*

Species	N	P	K	Water	Ash	Raw-fat	Fiber	Protein	Carbon
A. auriculiformis	1.81	0.10	0.82	6.14	3.62	6.01	31.52	12.23	7.93
A. mangium	2.21	0.08	0.48	6.99	4.69	4.70	27.42	17.74	5.47

Table 7. Variation of nutrition in different forest soil

Treatment	Before planting		3-year-old		6-year-old	
	Humus	Total N	Humus	Total N	Humus	Total N
E. leizhou No.1	0.98	0.06	1.06	0.04	1.11	0.07
A. auriculiformis	1.03	0.08	1.80	0.09	1.96	0.09
E. + A.	0.08	0.07	1.54	0.07	1.81	0.08

Conclusion

Acacias have been extensively planted in various habitats in Southern China but the exotic species are still new to the area and many of their biological and ecological habits are not yet well understood. Elimination and provenance trials should be strengthened and research should focus on utilization of acacia timber and its by-products. As the scale of acacia planting increases, control of pests and diseases must be taken seriously to prevent serious problems. In these areas, we sincerely look forward to the technical and funding support and collaboration of international organizations and developed countries.

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Acacias for Rural, Indusrial, and Environmental Development in India

B.S. Nadagoudar

Introduction

Acacias are important indigenous species throughout India, particularly in arid and semi-arid areas. In rural areas, acacias are used for fuelwood, fodder, small timber, agricultural implements, rural house construction, tannin extraction, tooth brushes, gum as human food, ayurvedic medicines, and shampoo. In industry, they are used mainly for tannin in leather dying and, in the case of *A. catechu*, as an edible product *katha*. There is also some use for timber. Acacias are particularly important in India's drive to recover wastelands and provide fuelwood. This paper attempts to illustrate the role of acacias in rural, industrial and environmental development in India.

Table 1 lists the 18 most commonly found *Acacia* species in India.

Distribution

Indigenous acacias are found throughout India, except in the mid and upper Himalayan region. *A. catechu* is found in the tropical region of the Garhwal Himalayas (Uttar Pradesh) comprising Doon Valley and Shiwalik ranges up to 1,200 m elevation. Evergreen or semi-evergreen deciduous forests characterize this area (Paliwal 1988; Gupta 1986). In the natural forests of Bundelkhand region (Uttar Pradesh), the different acacias found are *A. catechu*, *A. leucophloea*, and *A. nilotica* (Srivastava 1981).

A. nilotica and *A. senegal* are important among other tree species of arid zone of Rajasthan in the north (Solanki et al. 1990). *A. nilotica*, *A. leucophloea* and *A. planifrons* are common in peninsular plains of India (up to 650 m altitude).

Environmental Development with Acacias

Acacias help to protect wastelands from being further degraded and tolerate industrial pollution.

Table 1. Common acacia species in India.

Scientific name	Common names (language)
A. albida	African kikar (Hindi)
A. auriculiformis	Bangali jyali or haladi meese (Yellow mustach) (Kannada), bangali babul, sona jhuri, (Hindi), Akashmoni (Bengali)
A. canophylla	Blue wattle (English)
A. catechu	Kachu, kaggali (Kannada), cutch, khair (Hindi, Marathi & Punjabi), khadira (Sanskrit), kachu, kadiramu, sundra (Telagu), kadiram, karungalli (Tamil), kadori (Marathi), khayar (Bengali), kherio-baval (Gujarathi), khoiru (Oriya), khoria (Assamee)
A. concina	Seege (Kannada), shikakai (Hindi)
A. dealbata	Exotic - silver wattle (English) pahadi babool (Hindi)
A. decurrens	Peek jyali (Kannada), green and silver wattle (English), hara babul (Hindi)
A. farnesiana	Exotic - cassie flower (English), gandh babul, dar babul (Hindi)
A. ferruginea	Banni (Kannada), shami (Sanskrit), khor (Hindi), ansandra (Telagu), kaigu, khaiger (Gujarathi), khair, pandhra (Marathi), velvelam (Tamil)
A. leucophloea	Bela or toppale or bili jyali (Kannada), safed babul, saefed kikar, raunj, rhea, rinj (Hindi), reru (Punjabi), arunjroong (Rajasthni), haribaval (Gujarathi), hewar, runj, orinja (Marathi), patacharyamaram (Malayalam), safed babul (Bengali), tellatumma (Telagu), velvayalam (Tamil), vilayati babul (Hindi - Madhya Pradesh)
A. mearnsii	Exotic - black wattle (English)
A. melanoxylon	Exotic - Australian black wood (English), kali lakadi (Hindi)
A. modesta	Phulahi (Punjabi), phulai (Hindi)
A. nilotica	Kari jyali, gobbli (Kannada), babul, kikar desi, kikar (Hindi, Punjabi), godi babul, vedi babul, babhul (Marathi), babla (Bengali), balsaria, baval (Gujarathi), bauhra, bambuda (Oriya), karuvelamaram, karuvelei (Tamil, karuvelun, khadiram (Malayalam), nellatumma, tumma (Telagu)
A. nilotica var. *cupressiformis*	Ramakati (Hindi)
A. planifrons	Kode mullu (Kannada), udai (Hindi)
A. tortillis	Israeli babul, Israeli kikar (Hindi)
A. senegal	Hire jyali (Kannada), kumata, kheri (Hindi), kumta (Rajasthani and Punjabi), goradiobabul (Gujarathi), khor (Punjabi), svetkhadira (Sanskrit)

Table 2. Recommended acacias for different types of degraded lands.

Species	Coastal, sandy soils	Saline soils	Clayey soils	Ravines	Uplands	Dry areas	Sodic soils	Alkaline soils	Waterlogged soils
A. auriculiformis	x	x							x
A. nilotica		x	x	x	x	x	x*	x	
A. tortilis			x		x	x	x	x	
A. catechu		x		x					
A. leucophloea				x					
A. mearnsii					x				
A. albida						x			
A. farnesiana							x		
A. pennatula							x		

*var. *cupressiformis* *Sources:* Hegde (1988), Tyagi (1986), Pathak (1988), and Jain (1984), Vimal and Tyagi (1986), Yadav (1981), Gosh (1984)

Role in Wasteland Development

Development of wastelands (saline, alkaline, waterlogged, and highly eroded soils; ravines; degraded forests; steeply sloping areas) is a priority issue in India. In 1985, when the National Wasteland Development Board was established, the Government planned to reforest nearly 5 million ha of wasteland every year. Acacias are playing a large role in this effort (Table 2).

In calcareous soils (alfisols) under arid conditions (Jhansi), *A. tortilis* survives better than *A. nilotica* (Anon. 1988a; Pathak and Gupta 1990).

Summarizing studies at the Central Arid Zone Research Institute (CAZRI), Shankarnarayan and Dass (1986) note that *A. tortilis* is very hardy, can withstand harsh climates, and is best for fuelwood in Western Rajasthan. Fuel yield varies from 40-53 tons per ha (air dried) after 12 years. A cost-benefit ratio of 1:2 has been observed in entire plantations.

A. albida, A. auriculiformis, A. mearnisii, A. senegal, A. seyal, and *A. tortilis* are recommended for development of arid and semi-arid wastelands (Tokey and Chaudhary 1987). In social forestry plantations, *A. nilotica* and *A. auriculiformis* are used in barren lands of Madhya Pradesh (Prasad and Chadhar 1990).

A. tortilis and *A. canophylla* with grasses are few examples of most viable silvi-pastoral systems in shifting sand-dune areas (Tokey 1988). For afforestation of semi-arid tracts with partial shifting sand dunes *A. nilotica, A. tortilis* are more promising.

Soil Improvement and Conservation

Trees improve soil fertility by adding organic matter and releasing nutrients through litter fall. *A. senegal* was found to increase organic carbon of surface soil by 93% and nitrogen by 95% in desert soils (Agarwal and Lahiri 1977).

Studies made in vertisols of Karnataka, India, have shown that a strip of trees across a slop considerably reduces run-off. Rainwater run-off loss was least when *A. auriculiformis* was used, followed by *A. nilotica* and *A. catechu* (Itnal 1986).

A. nilotica appears to improve soil properties (soil pH, EC, organic carbon, available N and P_2O_5; cation exchange capacity, or CEC; bulk density; and field capacity) more quickly than *A. tortilis* (Hazra 1990).

Tolerance of Industrial Pollution

Degraded environment, air and water pollution, and acid rain have been highly debated issues around the world since the 1980s. Although industrialization has many benefits, effluents released in manufacturing processes are hazardous to both biotic and abiotic components of the ecosystem. Finding a balance between a modern industrial environment and a healthy natural environment involves a search for pollution-resistant tree species. *A. nilotica* finds a place in the list of pollution-tolerant species prepared by Sharma et al. (1987), and *Acacia* spp. more broadly have been cited by Sharma (1984).

At the Centre for Application of Science and Technology for Rural Development (CASTFORD) in Pune, Maharashtra, *A. auriculiformis* performed well with 95% survival using sewage water for irrigation (Das and Kaul 1992). Other species recommended for waste water or industrial effluents are *A. mangium*, *A. nilotica* spp *indica*, and *A. tortilis*.

Industrial Uses

Tannin extracted from acacias is used in the leather industry, but specific Information on their tannin quantity, quality, and uses is lacking. Tannin extracted from *A. catechu* is edible one and is eaten as an astringent along with betelvine leaves and areca nut. A small piece of catechu (tannin) is used with cinnamon and nutmeg to treat toothaches and loss of voice. Information on acacias' commercial exploitation for industrial timber is also scanty.

Rural Development

Like in many developing countries, firewood is the major source of energy in Indian households, accounting for nearly 80% of energy use. In Tamil Nadu, in southern India, three acacias contribute nearly 35% of all the annual fuelwood requirements (4.88 metric tons): *A. nilotica* (23%), *A. planifrons* (7%), and *A. leucophloea* (5%)(Venugopal 1989).

Agroforestry Practices

Agroforestry in various forms has long been practiced by farmers in India. Traditionally, farmers use acacias (particularly in vertisols of arid and semi-arid zones) along field borders, bunds, in wastelands, and along streams and river banks. According to Singh (1990), farmers in Madhya Pradesh prefer to grow *A. nilotica* on bunds and field borders; after five years, they remove the side branches every year for sheep and goat fodder, fuel, field fencing, and agricultural implements. On an average each tree yields about 400 kg per year.

In the Bundelkhand region of Uttar Pradesh, *A. nilotica* accounts for nearly 40% of the trees found in farmers' fields. In dry areas only 8 trees per ha are seen as against 14.5 trees in irrigated areas

(Tiwari and Sharma 1990).

In the evergreen forests of Sikkim, Eastern Himalaya, acacias are not found either in natural forests or in traditional agroforestry systems. Instead, large cardamom (*Amomum subulatum*) a traditional plantation crop, is grown (Venugopal 1986).

Role in Recommended Agroforestry Practices

Recommendations based on research results suggest that *A. nilotica* grown on an eight-year rotation along field boundaries assures good profit to the farmer (Pathak 1988).

Silvipastoral

In silvipastoral systems, critical appraisal of the tree-grass compatibility is essential for a viable system. In Avikanagar (Rajasthan), *A. nilotica* yields 6.56 kg top feed per tree with two cuts a year (Sabnis et al. 1989). Palatability ratings for leaves are higher in *A. nilotica* than *A. senegal.*

In silvipastoral systems for wastelands, *A. tortilis, A. senegal, A. albida, A. nilotica* (var. *cupressiformis*) are promising in arid western plains of Uttar Pradesh, Rajasthan, Gujarath and semi-arid regions of Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh and Karnataka. *A. nilotica* gave a benefit:cost ratio of 1.56 in silvipastoral systems in highly eroded ravines of the arid zone (Dhruvanarayana and Ram Babu 1984).

For arid areas, Deb Roy et al. (1980) also suggest *A. tortilis* with grasses (*Cenchrus ciliaris, Lasiurus sindicus*) and legumes (*Atylesia* sp. and *Siratro*). *A. tortilis* survives better than other tree species, with higher mean annual height, collar diameter and dbh increment, and produces leaves and pods for fodder (Anon 1988). Although that report observes that its shade slightly reduces the total forage production by the grasses and legumes, Shankarnarayan (1984) claims that the species does not affect grass yields.

A. tortilis also forms an important component of silvipastoral systems in uncultivable wastelands (very poor soils and low rainfall) of Bihar. There, fuelwood yield at 6 years was 22.69 tons per ha; fodder yield was 0.91 tons per ha (Srivastava 1986).

Wind and Soil Protection

Arid regions of India experience high winds during the post-monsoon period (7.3 km/hr in December, up to 20 km/hr in May), causing damage to standing field crops. In terms of wind resistance, Tewari et al. (1989) grade acacias as *A. tortilis* > *A. nilotica* > *A. senegal*.

For agroforestry systems designed to improve soil productivity and land sustainability, *A. ferruginea* at low densities is found to increase the yield of under-crop significantly (Nadagoudar 1990; Singh and Osman 1987).

In Gujarat, under sandy saline soil conditions *A. nilotica* performed better than *A. auriculiformis* while in Karnataka under shallow gravelly soils over basaltic rock *A. auriculiformis* was better. In loamy sands of Maharashtra (Pune) *A. nilotica* var. *cupressiformis* performed better (Hegde et al. 1990).

In red soils of Bundelkhand (Uttar Pradesh) for silvipastoral systems, *A. tortilis* again appears to be better suited than other species based on its survival (98.6%) and overall assessment (Singh and Pathak 1990). In the arid areas of Rajasthan, also, the species holds promise on a wide range of soils and rainfall, and on a wide range of soils and rainfall, and for a wide range of purposes (social forestry, village fire wood and fodder plantations, dune stabilization, shelterbelt plantations)(Bhati 1984; Soni 1984; Muthana 1984).

For Punjab, Sidhu (1986) recommended *A. catechu, A. nilotica, A. modesta, A. tortilis* and *A. auriculiformis* as suitable species for agroforestry in different agro-climatic zones.

Diversity of Ground Vegetation under Acacias

In plantations and natural regeneration, mixtures of different species provide a wider range of benefits and biomes. In seven-year-old plantations, *A. auriculiformis* had a ground flora of an average of six species; the highest number of species per square meter was obtained with *Grevellea robusta* (15) and the lowest was with *Eucalyptus tereticornis* (3)(Bhaskar and Dasappa 1986).

Forage production and ground flora are both important for a successful silvipastoral system. Although the ground flora was in no way inferior under *A. senegal* (Agarwal et al. 1976), forage production was very low (Ahuja et al. 1978).

Bio-energy Production

In energy plantations, close planting and early harvesting is a purposive method known as "short-rotation forestry." Species like *A. auriculiformis, A. nilotica, A. senegal* and *A. tortilis* can be used in bio-energy production (Vimal and Tyagi 1984). Studies in Tamil Nadu (assured rainfall area) have shown that *A. nilotica* can yield 30 tons oven-dry biomass per ha at 18 months, and 85 tons per ha at 36 months; *A. tortilis* yielded only 18 tons per ha at 18 months and 87 tons per ha at 36 months (Ukkira Moorthy and Swaminathan 1986). Under semi-arid conditions, after 10 years of planting *A. tortilis* can yield up to 12 tons wood per ha (Desai and Patil 1986).

With regard to calorific value of fire wood as observed in Rajasthan: *A. tortilis* gives 4,333 kcal per kg and a mean annual increment (MAI) for height of 95.7 cm; *A. nilotica* spp *indica* gives 4267 kcal per kg, with height MAI of 89.8 cm (Dass and Shankarnarayan 1984).

Role in Apiculture

Acacias play a role in honey production also. *A. auriculiformis* and *A. catechu* have nectar and pollen ratings of N3 and P3; *A. senegal* has N2 P2 ratings (Mishra 1988; Mishra and Kumar 1987).

Wood Properties of Some Acacias

Anatomy is a helpful tool for understanding the economic utility of timber, in addition to phylogeny and physiological processes. *A. nilotica* has approximately three times more heartwood than sapwood at age 9.5 years (Kaushik et al. 1984). The wood is composed of wood fibers and less moisture throughout the year (Ghouse and Iqbal 1982), making it suitable for firewood and agricultural implements.

Wood properties of acacias require further study to make the trees more useful.

Tree Improvement

Provenance tests are a part of tree improvement work and involve screening the available range of natural genetic variation in a species to determine the best material for use and breeding at a specific site. In a study at Kanpur (Uttar Pradesh), *A. nilotica* ssp. *indica* from Banaskantha (Gujarat) showed better height, diameter, number of nodes and branch length than other provenances from Karnataka, Maharashtra, Andhra Pradesh and Uttar Pradesh (Shivkumar and Banerjee 1986).

Agroforestry Research under ICAR

In 1983, the Indian Council of Agricultural Research (ICAR) started a large agroforestry research program, coordinated throughout the country. ICAR-supported work is now in progress at 31 locations in 5 regions. As seen in Table 3, one or another of the indigenous *Acacia* species is being tested in every region except for the Himalayan region (comprising Jammu-Kashimir, Himachal Pradesh, Meghalaya, Sikkim, Manipur, Assam and parts of Uttar Pradesh)(Anon. 1990, 1992).

Table 3. Acacias studied in the All-India Agroforestry Research Programme.

Region	States included	Acacias studied
Gangetic plains	Punjab, Uttar Pradesh and Bihar	*A. nilotica, A. catechu, A. auriculiformis*
Humid and subhumid	Tripura, Orissa, West Bangal and Southern Bihar	*A. auriculiformis*
Arid and semi-arid	Rajasthan, Haryana, Gujrat, Maharashtra, Andhra Pradesh, Madhya Pradesh and Southern Utta Pradesh	*A. nilotica, A. leucophloea, A.tortilis, A. senegal*
	Tropical Karnataka, Kerala, Tamil Nadu, Coastal and Eastern Maharashtra, Andaman and Nicobar	*A. leucophloea, A. planifrons, A. auriculiformis, A. nilotica*

Even in the Himalayan region, where acacias do not do well, *A. auriculiformis* is promising among 4 species tested at Jorhat (Assam) and 16 species tried at Shillong (Meghalaya)(Anon. 1992), and has been found suitable for different agroforestry systems in Meghalaya (Chauhan and Dhyani 1990).

In addition to the ICAR work on agroforestry systems, research on germplasm collection and improvement is also in progress at the following centers:

- Mettupalayam (Tamil Nadu) - *A. leucophloea*
- Parbhani (Maharashtra) - *A. nilotica* var. *cupressiformis*
- Rahuri (Maharashtra) and Ludhiana (Punjab) - *A. nilotica*
- Agartala (Tripura) - *A. auriculiformis*
- Fatehpur (Uttar Pradesh) - *A. tortilis*

Summary

Acacias play a large role in Indian agriculture and other land-based biological activities. The 20 most commonly seen species include *A. nilotica, A. tortilis, A. catechu, A. leucophloea* and *A. planifrons* An exotic species, *A. auriculiformis* is becoming common. They play important role in wasteland development, agroforestry, soil improvement and conservation, apiculture, bio-energy production, and are environment-friendly. Research is needed on wood properties and preservation, and tree improvement of indigenous species. With the support of Indian Council of Agricultural Research, agroforestry research centers of the All-India Co-ordinated Research Project on Agroforestry have started germplasm collection and tree improvement of acacias, in addition to management of acacias in agroforestry systems.

Discussion Notes

Comment: Regarding germplasm improvement, note the need to improve exotic species as well as indigenous ones. For example, *A. auriculiformis* has deteriorated in some stands in India. Further collection from the native ranges of desired species would be desirable.

Question: Are any other acacias besides *A. catechu* used in ayurvedic medicine?

Answer: No.

Q: In the reforestation of semi-arid and arid areas, are end uses considered?

A: Yes, fuelwood being the priority use, followed by soil conservation and fodder.

Comment: It is interesting that *A. auriculiformis* appears to do well on saline soils; in Pakistan it has not performed well on saline soil.

Q: Is there any information on the extent of existing use for non-wood uses? Or on the involvement of communities in tree-planting?

A: Regarding your first question, no, I have no information on amounts of sheep and goat fodder used. On your second question: social forestry and its programs in India are now more than 10 years old. Locally preferred species are planted in common lands by the communities. In plantations, Forest Department staff plant the seedlings and turn management over to local people, who receive one half of the profit from the tree harvest. The other half goes to the Government.

Q: Is *A. arabica* a synonym for *A. nilotica*?

A: Yes.

Q: I gather that *A. mangium* is not important in India? Any work on its hybridization?

A: Generally, the species demands too much moisture for wide use in India. Paper mills in the South (the more humid area of the country) are doing some work with *A. mangium*. But I know of no systematic analysis of its hybridization.

Q: What is the importance of non-wood products for rural communities in economic terms?

A: Because most of this information is in the form of unaccounted trade, there is no systematic account to date.

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Tree Improvement of *Acacia mangium* for Industrial Forest Plantation Development in Indonesia

Hendi Suhaendi

Introduction

Industrial forest plantation development is a priority program in Indonesia, in accordance with efforts to increase the potential of production forest areas. The main objectives are to provide a stable and long-term supply of raw materials for wood and wood-working industries, wider employment opportunities, and increased foreign exchange. For the 15-year period that began in 1984, the government has planned to establish a total area of 6.2 million ha. With existing forest plantations, largely on Java, amounting to about 1.8 million ha, this means that 4.4 million ha are to be established by 1999/2000. The total annual yield at the harvest time is expected to be 90 million m^3 per year (based on assumed productivity or mean annual increment of 15 m^3/ha/year).

For this intensive effort, highly productive forest stands need to be established, requiring high-quality seed/propagules/planting materials and intensive silvicultural practices. The former can be obtained from a series of tree improvement activities.

Acacia mangium Willd. is a priority species for the Industrial Forest Plantation program, since it grows in Indonesia in natural forests as well as plantations. Its main industrial uses are for (1) pulp, paper and rayon, (2) building material and furniture, and (3) energy.

This paper presents tree improvement activities of the Industrial Forest Plantation development on *Acacia mangium*.

Distribution

Acacia mangium grows naturally in eastern Indonesia, in Maluku and Irian Jaya. In Maluku, it is found in Trangan and Ngaiber (Aru Island), Sula, Taliabu and Tege islands, Kairatu and Waesalam (Seram Island) and the southern part of Maluku. In Irian Jaya, it is found in Manokwari, Sedai, along the Digul River, Fakfak, and Merauke (Sindusuwarno and Utomo 1980). As a priority industrial plantation species, *A. mangium* has been planted widely in Sumatra, Java, Kalimantan, and Sulawesi.

The National Tree Improvement Program

Early in 1990, the Forest Research and Development Centre (FRDC) in Bogor, one of two Centres under the Agency for Forestry Research and Development (AFRD), drew up a National Tree Improvement Program for Supporting Industrial Forest Plantation Development in Indonesia (Suhaendi 1990). Its objectives of the program are to:

(1) increase the productivity of industrial forest plantations and improve the quality of forest products through the supply of

high-quality seeds/propagules/ planting materials of selected, fast-growing and highly productive tree species suitable on sites throughout Indonesia

(2) coordinate all tree improvement research in Indonesia

To fulfill these objectives, the following research has been proposed:

(1) species trials
(2) provenance trials
(3) selection of plus trees
(4) half-sib progeny tests
(5) establishment of seed orchards and clone banks
(6) phenological studies and controlled pollination
(7) conventional vegetative propagation techniques
(8) tissue culture techniques
(9) isozyme analysis
(10) breeding for pest and disease resistance

Tree Improvement

Species Trials

Matching species and sites is the first stage in successful plantation establishment. Species trials provide basic information on which this decision can be made. In late 1983, the University of Gadjah Mada (UGM) established fuelwood species trials in Patiayam, Central Java. These trials tested 23 species, including *A. mangium* and *A. auriculiformis*. At three years of age, both *A. auriculiformis* and *A. mangium* had good height and diameter growths (Table 1). The calorific values of the wood from this trial still need to be determined.

UGM began another acacia trial testing four species at Wanagama I, Yogyakarta, in 1984. *A. mangium* grew the fastest, with an average height at two years of 7.9 m, followed by *A. auriculiformis* (4.6 m), *Acacia silver* (4.1), and *Acacia oraria* (2.6m)(Hardiyanto et al. 1992).

At Subanjeriji, Palembang, South Sumatra, combined species and provenance trials (five provenances of *A. mangium*, one provenance of *A. crassicarpa*, one provenance of *A. cincinnata*, and two provenances of *A. auriculiformis*) were begun by the Directorate General of Reforestation and Land Rehabilitation (DGRLR) in December 1983. The trials used a randomized complete block design with ten blocks, nine treatments (provenances), and four-tree plots per seedlot (PT Inhutani I 1990). These combined trials have not yet been evaluated.

The Centre for Reforestation Technology (CTRB) in Banjarbaru, South Kalimantan, under AFRD, has also conducted species trials in pure *Imperata cylindrica* (alang-alang) sites since the 1986-1987 planting season. One year after planting (Vuokko and Hadi 1988), the promising species were *A. mangium, A. auriculiformis, A. crassicarpa, A. leptocarpa, Paraserianthes falcataria, Anthocephalus chinensis, Cassia siamea, Eucalyptus camaldulensis, Gmelina arborea*, and *Leucaena leucocephala*.

Two years after planting (Hadi and Adjers 1989), the most promising species were *A. crassicarpa, A. mangium, A. leptocarpa, A. cincinnata, A. auriculiformis*, and *Paraserianthes falcataria*.

Two years after planting (Hadi et al. 1990). *Acacia* spp., *Cassia siamea*, and *Gmelina arborea* can be planted on

Table 1. Growth of the best-performing 15 species in fuelwood species trial at Patiayam, Central Java, at three years.

Rank	Species	Height (m)	Diameter (cm)
1.	*Sesbania grandiflora*	9.4	14.1
2.	*Eucalyptus urophylla*	9.3	10.9
3.	*Gmelina arborea*	9.0	20.2
4.	*Acacia auriculiformis*	8.3	10.5
5.	*Acacia mangium*	8.0	9.1
6.	*Eucalyptus alba*	7.9	9.9
7.	*Eucalyptus deglupta*	7.9	9.5
8.	*Cassia siamea*	7.6	9.5
9.	*Gliricidia* sp.	7.2	8.3
10.	*Leucaena leucocephala* K72	6.7	9.4
11.	*Leucaena leucocephala* K67	6.6	9.4
12.	*Leucaena leucocephala* K29	6.5	9.4
13.	*Samanea saman*	5.7	8.7
14.	*Adenanthera* sp.	5.6	9.4
15.	*Albizia procera*	5.5	8.4

Source: Hardiyanto et al. (1992)

alang sites, with less intensive weeding than required for *Paraserianthes falcataria*.

Provenance Trials

Provenance trials of *A. mangium* have also been established, especially by AFRD, DGRLR, the State Forest Enterprises, and the University as presented in Table 2. In general, the trials in Table 2 have not yet been evaluated. The trial at Wanagama I (no. 6), containing 12 provenances (Papua New Guinea—3, Queensland—7, and Indonesia—2) showed no differences in height and diameter growth among provenances at 17 months (Na'iem et al. 1985). At six years, only diameter growth showed significant differences, with the Morylyan Bag, Queensland provenance performing best (33.4 cm), and the Iriomo River, PNG worst (17.8 cm). All provenances showed multistem growth. Still, each provenance also had single-stem individuals (Hardiyanto et al. 1992).

Research from CTRB-AFRD in Banjarbaru showed that the best provenance for Riam Kiwa (Banjarbaru) was Claudie River (Queensland), which at 2.5 years old reached an average height of 11.1 m with mean annual increment (MAI) of 38 m^3/ha/year; the worst provenance was Sanga-Sanga (East Kalimantan), which at the same age attained 7.5 m, with MAI of 11.1 m^3/ha/year. At 5 years, the Claudie River provenance reached 20.0 m (MAI 58 m^3/ha/year), while Sanga-Sanga was only

12.7 m (MAI 17.5 m^3/ha/year)(Schildt 1992).

Other tests in Banjarbaru showed that at 35 months, provenances from Papua New Guinea showed height growth of 14.9 m with MAI of 43 m^3/ha/year, and the Subanjeriji-Palembang provenance grew only 13.1 m (MAI of 27 m^3/ha/year)(Schildt 1992).

A provenance trial in Nanga Pinoh (no. 7) containing 14 provenances, all from Queensland, showed that at 3 years height did not show any significant differences among provenances. Differences in diameter, however, were significant. Another provenance trial in Riam Kiwa (no. 8) using 30 provenances (Queensland—16, Maluku—2, Irian Jaya—3, Sabah—4, and East Kalimantan—2) showed that differences among provenances for both height and diameter were nonexistent at two years (Hardiyanto et al. 1992).

Selection of Plus Trees

For seedling seed orchards and clonal seed orchards, the following have been selected:

(1) 145 plus trees in Subanjeriji plantation forest, South Sumatra (PT Inhutani I 1988)

(2) 55 plus trees in Benakat plantation forest, South Sumatra (Salim 1992, pers. comm.).

(3) 35 plus trees in Banjarbaru plantation, South Kalimantan (Faidil 1992, pers. comm.).

Selection of plus trees in natural forests has not yet been carried out.

Half-Sib Progeny Test

The first half-sib progeny test, containing 30 open-pollinated families, was begun by PT INHUTANI I in Rebang Ds., Lampung Province, in 1987, using a randomized complete block design with five blocks (replications), 30 families and 5-line tree plots (Suhaendi 1991).

Another half-sib progeny test, containing 200 open-pollinated families, was conducted by the Centre for Seed Technology under AFRD in Parung Panjang, about 70 km from Bogor. A randomized complete block design was used with 7 blocks, 200 families, and 5-line tree plots. Planting was done in February 1992 at a spacing of 3 x 3 m.

Other half-silb progeny tests of *Acacia* spp. have been carried out by UGM in Wanagama I, Yogyakarta.

Establishment of Seed Orchard and Clone Banks

An evaluation of half-sib progeny tests containing 30 open-pollinated families in Rebang Ds, Lampung showed that the genetic inheritance pattern of total height is very strong, with this character controlled by genetic factors as much as 77% at 0.5 years and 86% at 1.5 years (Suhaendi 1991). By contrast, the genetic inheritance pattern of stem diameter proved very weak, as much as 89% (0.5 years) and 96% (1.5 years) environmentally controlled. It seems that total height could be used as a roguing criterion to convert a half-silb progeny test plantation into a seedling seed orchard.

Table 2. Some *A. mangium* provenance trials established in Indonesia.

No.	Year of planting	Location	Number of provenances and replications	Executing agencies
1.	80/81	Subanjeriji (South Sumatera)	3 provenances 5 replication	DGRLR and PT Inhutani I
2.	81/82	Subanjeriji	4 provenances	DGRLR and PT Inhutani I
3.	82/83	Subanjeriji	3 provenances	DGRLR and PT Inhutani I
4.	83/84	Subanjeriji	5 provenances 10 replications	DGRLR and PT Inhutani I
5.	84/85	Subanjeriji	12 provenances 4 replications	DGRLR and PT Inhutani I
6.	83/84	Wanagama I (Yogyakarta)	12 provenances	UGM
7.	85/86	Nanga Pinoh (West Kalimantan)	14 provenances	DGRLR
8.	86/87	Riam Kiwa (South Kalimantan)	30 provenances 4 replications	CTRB-AFRD
9.	88/89	Riam Kiwa	4 provenances 4 replications	CTRB-AFRD
10.	88/89	Benakat (South Sumatera)	5 provenances 3 replications	CTRBe-AFRD
11.	88/89	Majalengka (West Java)	6 provenances 5 replications	Perhutani

DGRLR = Directorate General of Reforestation and Land Rehabilitation; PT. Inhutani = A State Forest Enterprise, working outside Java; UGM = University of Gadjah Mada; CTRB-AFRD = Centre for Reforestation Technology in Banjarbaru, under the Agency for Forestry Research and Development; CTRBe-AFRD = Centre for Reforestation Technology in Benakat; Perhutani = Perum Perhutani, a state forest enterprise (public enterprise), working especially in Java. *Sources*: PT Inhutani (1990/1991) and Suhaendi (1992)

Under the supervision of Dr. Garth Nikles from the Queensland Forest Research Institute, Queensland Forest Service, an excellent seed orchard will be established in Banjarbaru, South Kalimantan, by CTRB-AFRD. Figure 1 shows the flow chart of planned seed orchard development.

The establishment of clone banks has just begun.

Phenological Studies and Controlled Pollination

Djapilus and Adjie (1992) have observed flower morphology and fruiting of *Acacia mangium* in Lampung. They found that:

1) Abundant flowers on the crown did not depend on direction, but on the amount of sunlight absorbed by the crown. The part of crown facing east bore the most flowers. Terrain also affects the amount of light hitting the tree crown.

2) Flowers open simultaneously with sunrise, reaching a maximum opening at midday, between 9.00 and 11.30 a.m. This is correlated to increasing temperature, or is affected by weather.

3) Pistil (female organ) position is a bit higher (1-1.5 mm) than anther (male organ).

In Subanjeriji, South Sumatra, natural hybrids of *A. mangium x A. auriculiformis* showed clear promise. The growth was faster than *A. mangium*, the wood quality was similar to *A. auriculiformis*, and the flowering period was faster, with many starting to flower before one year of age.

Conventional Vegetative Propagation

Vegetative propagation by air layering carried out by FRDC using plus trees in Subanjeriji yielded only 30% success, due to problems in implementation and the scarcity of skilled climbers. However, vegetative propagation through air layering seems to be of limited application in establishment of large-scale clonal forestry, since only a limited number of air-layered materials can be produced from each tree.

An alternative to air layering is micropropagation of explants, especially by tissue culture.

Vegetative propagation (macropropagation) tested by FRDC is attempting to foster sprouting by girdling (in which the cambium is partially removed) close to the ground level. Preliminary results show that this species sprouted vigorously, and on the bottom part of partly removed cambium sprouted abundantly, and could be used as rooted cutting materials. The sprout produced is juvenile, so for better sucess and survival IBA hormone is applied at suitable concentrations. This technique has proven successful at P.T. Indah Kiat's concession in Pekanbaru, Riau Province.

Controlled pollination between *Acacia mangium x Acacia auriculiformis* continues at FRDC and SEAMEO-BIOTROP, both in Bogor, but the result is not yet satisfactory.

Tissue Culture

FRDC research on tissue culture of *A. mangium* has not been successful due to browning symptoms. However,

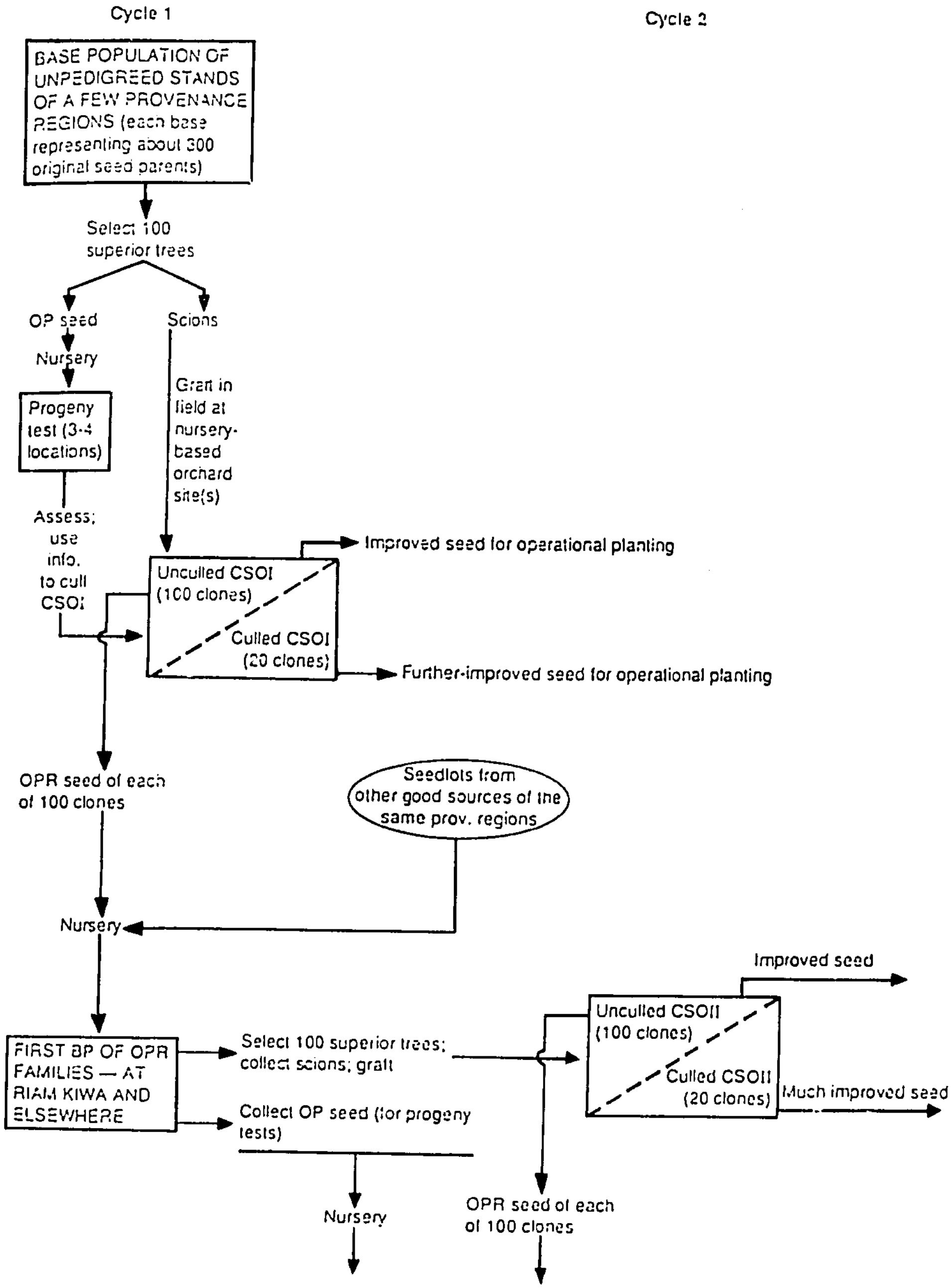

Figure 1. Flowchart showing the first and part of the second part of the cycle of system for breeding and seed production recommended for *A. mangium* in South Kalimantan. 'BP' means breeding population ; 'OPR' stands for open-pollinated families ; 'OPCSO' stands for open-pollinated clonal seed orchard.

SEAMEO-BIOTROP has successfully established a field test of *A. mangium* from tissue culture (Umboh 1986).

Setiawan et al. (1990/1991) studied the growth and rooting system of *A. mangium* plantlets produced by tissue culture, with the following results:

(1) Height and diameter growth after 2.5 years of field test was better for *A. mangium* trees produced by tissue culture than for seedlings.

(2) The root system of *A. mangium* plants produced by tissue culture is very compact, massive, and has many secondary roots. Although there is no tap root, three to four adventitious roots developed vertically and assumed the function of tap root.

Planting stock production from *in vitro* clones of *A. mangium* plus trees and hybrid *A. mangium x A. auriculiformis* continues at SEAMEO-BIOTROP. BIOTROP's next five-year plan calls for identification of desired genotypes and the silvicultural manipulation of clones in plantations (Umboh et al. 1992).

Isozyme Analysis

As part of its biotechnology program, SEAMEO-BIOTROP has conducted isozyme analysis on *A. mangium* and hybrid *A. mangium x A. auriculiformis* (Umboh et al. 1992)

Breeding for Pest and Disease Resistance

Breeding for pest and disease resistance has just started. Recently SEAMEO-BIOTROP collected 5 different *A. mangium* clones, 5 natural hybrid clones of *Acacia,* and about 40 artificial hybrid clones, consisting of 31 hybrid clones of Am x a (female parent of *A. mangium).* It is hoped that from among these 50 clones, individuals resistant to identified pests and diseases can be found and used in breeding for resistance (Umboh et al. 1992).

Discussion Notes

Due to competing land uses, industrial forest plantations must be established on marginal land (grassland, bare land, 'critical' land, and 'unproductive' land). So far 1.8 million ha is under plantation in Java.

One constraint is the availability of quality seed for planting stock.

Q: Is there a marketing plan for this program?

A: Marketing is not a problem in view of the existing demand from fiber companies and the international market.

Q: Why haven't acacia plantations been established in the eastern islands, where the species are indigenous?

A: This has been proposed by research, but decision makers have judged other factors more important.

Q: Will FRDC's program involve rural people?

A: The main goal is to substitute extraction from the natural forest in response to increased international pressure on Indonesia. The response requires vast areas of land and a huge effort; hence the commercial-scale approach.

Q: Regarding marketing again, there is a great difference in wood quality between plantation-grown trees and natural forest stands. How will Indonesia ensure that the plantation-grown trees can be utilized by the plywood industry?

A: By relying on three species with which the industry has the most experience: *A. mangium, Eucalyptus urophylla,* and *Paraserianthes falcataria.*

Comment: Building material for low-quality material is based on composites. Regarding market and local use, indigenous species can and should be used for local consumption, while fiber companies can use the exotics that they know better and for which they are sure of an international demand.

Q: You mentioned ongoing breeding efforts against pests and diseases; which pests and diseases are you breeding for?

A: That depends on the diseases and pests found at each of the nine regional institutes where seed is collected.

Q: Is there any plan to collect from plus trees in natural stands?

A: Yes, Mano p. institute in Irian Jaya is doing this, and we are interested in collaborating with other agencies internationally.

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Acacias for Rural, Industrial, and Environmental Development in Laos

Bounphom Mounda

Introduction to Laos

Lao PDR (Latitude 14-22.5°N, Longitude 100-107.5°E) is a landlocked country between China, Cambodia, Vietnam, Thailand and Myanmar, with a total area of 236,800 km² and an estimated 4,200,000 inhabitants as of 1990. Eighty-five percent of the population depends on agriculture and forestry, and 60% of the population is concentrated in the limited lowland area of the Mekong River basin, which comprises only about 20% of the country's area.

The climate is tropical to monsoon subtropical with a rainy season from April to September and annual rainfall of 1,200-2,300 mm. The minimum temperature is 18°C and maximum temperature is 28°C.

A nationwide reconnaissance forest survey made in 1992 estimated total forest area at 11,168,000 ha, around 47% of the total country area. Forests in Lao PDR are classified into eight forest types (Table 1).

Forest Plantations

In the last quarter of 1990, the forest inventory and management office, Department of Forestry, conducted a nationwide survey of forest plantation in Laos. It revealed that of the total 6,250 ha plantation area, only 3,000 ha could be classified as good-quality, sustainable

Table 1. Forest types found in Lao PDR, with area covered (,000s of ha) in each region.

Type of Forest	Northern	Central	Southern	Total
Dry Dipterocarp DD	54.9	69.9	1081.7	1206.5
Lower Dry Evergreen LDE	0.0	49.1	36.4	85.5
Upper Dry Evergreen UDE	104.2	654.2	302.6	1061.0
Lower Mixed Deciduous LMD	0.4	308.3	557.4	866.1
Upper Mixed Deciduous UMD	3345.4	2338.7	1764.8	7448.9
Gallery Forest GF	19.0	25.0	43.5	87.5
Coniferous S	13.0	93.5	25.7	132.2
Mixed coniferous/Broad-leaved MS	25.6	200.5	54.3	280.4
Total	3562.5	3739.2	3866.4	11168.1

Table 2. Species composition of forest plantations in Lao PDR.

Scientific name	Vernacular name	Proportion (%)
Tectona grandis	May sak	47.0
Pterocarpus macrocarpus	May dou	19.5
Afzelia xylocarpa	May Tekha	16.5
Eucalyptus sp	May Vick	6.0
Alstronia scholaris	May Tinpet	4.0
Others*		7.0

*includes: *Xylia, Dalbergia, Terminalia, Swietenia, Leucaena, Albizzia, Acacia, Dipterocarpus, Pinus, Gmelina, Cassia, Hevea, Anacardium, Melia, Styrax, Sterculia, Protium, Anisoptera,* and *Sindora.*

plantation. Most plantations have been established by State Forest Enterprises and provincial Forest Sections; some minor forest plantations organized by farmers and communities are found in a few provinces. Of the 30 species planted, teak (*Tectona grandis*) is the most common, representing nearly 50% of the plantation area (Table 2).

The Government's aim is to increase forest cover to 70% to ensure adequate production of tree products for economic development as well as environmental balance. To meet this aim in realistic reforestation work, we must ask, Which tree species should be planted and utilized in the short and long run, and what suitable techniques and methods shall be used to reach the objectives for our country?

Since 1988, Namsouang Silviculture Research Center, under the Lao-SIDA Forestry Program, has established species and provenance trials of both native and exotic species.

Introduction and Testing of Exotic Acacias

A. auriculiformis was first introduced to Laos more than 15 years ago, and is mainly used for shading and ornamental purposes. Using acacias for fuelwood is a practice still unfamiliar to Lao people.

In 1988 species/provenance trials of six acacias were established on 2.5 ha at 3 x 3 m spacing and measured annually. The trials tested seedlots of *A. auriculiformis* (4), *A. crassicarpa* (3), local *Afzelia zylocarpa* (1), *Acacia mangium* (3), *A. aulacocarpa* (1), and *A. leptocarpa* (1). The trial was damaged at age 16 months by fire. Further tests were suggested for *A. mangium*, *A. crassicarpa* , *A. leptocarpa*, and *A. auriculiformis.*

In 1989, species/provenance trials were established for *A. crasicarpa* and *A. mangium* using different seedlots than the first trial, but again difficulties were experienced.

In 1990, a third set of *Acacia* species/provenance trials were established, again at 3 x 3 m spacing, on

2.5 ha with 5 species: *A. auriculiformis* (6 seedlots), *A. mangium* (5), *A. aulacocarpa* (2), *A. holosericea* (2), and *A. crassicarpa* (3). The trial was weeded by discing and manual hoeing around each seedling, and seedlings were fertilized one month after planting using NPK 15-15-15.

In 1992, under Lao-ACIAR Project 9115, species/provenance trials of acacias were established on 5 ha to test 4 *Acacia* species and 4 *Eucalyptus* species, using a split randomized complete block with 4 replications.

Acacias and Rural, Industrial, and Environmental Development

According to the Government's strategy, reforestation and forest development must be linked with the living and food requirements of the Lao people. To this end, the Community Forest Plantation Section, Department of Forestry, has since 1991 supported farmers to grow their own minor forest plantations, either as pure plantations or in agroforestry systems for food production. The support is provided in the form of seedlings, forest technicians, and some fencing materials.

In the last two years, 525 ha of farmers' plantations have been established in 8 provinces; 30 ha were planted to *Acacia auriculiformis* and *Acacia mangium*. These species are gradually becoming more familiar to Lao farmers.

Recently, many private companies have become interested in investing in industrial plantations of acacias and eucalypts in Laos. Some have already started to establish plantations; the economics and market trends for acacias is under investigation now.

Discussion Notes

Q: Any information on indigenous species? For example, *A. insuavis*?

A: Not really; *A. insuavis* is found in homegardens grown for vegetable use.

Q: Is there a plan for a pulp/paper mill in Laos?

A: Two companies—Borapan, a Swedish firm, and the Lao-Finn Company—are exploring the potential for establishing mills in the future. Currently, the important market is the mill in Khon Kaen, Thailand.

Q: In what parts of the Government's plan have local people shown most interest?

A: In growing small plantations (0.16-0.24 ha) or combined plantings with agricultural crops, particularly agroforestry.

Q: Is land owned by the Government or by individuals?

A: Most land is government owned, but the new policy calls for sharing of land rights. There are many squatters on forest land who must be recognized. Also, to encourage industrial plantations, the government can provide 20-year leases.

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Acacias for Rural, Industrial, and Environmental Development in Malaysia

Darus Ahmad and L.H. Ang

Introduction

Although 850 of the approximately 1,100 species in the genus *Acacia* occur in Australia, Papua New Guinea and Indonesia (Boland et al. 1984), acacias are exotic to Malaysia. Nine species have been introduced: *A. mangium*, *A. auriculiformis*, *A. crassicarpa*, *A. aulacocarpa* *A. holosericea*, *A. cincinnata*, *A. farnesiana*, *A. podalyriaefolia*, and *A. richii*. Of these, only *A. mangium* Willd. and *A. auriculiformis* A. Cunn. ex Benth. are considered significat for rural, industrial, and environmental development in Malaysia.

A. mangium was introduced to Sabah, Malaysia in 1967 from Mission Beach (Queensland). About 570 plants from these seeds were raised at two sites, Sibuga (200 plants) and Ulu Kukut (370 plants). At Ulu Kukut, the seedlings were planted as firebreaks in a pine plantation (Pinso and Nasi 1991). Currently *A. mangium* is being intensively planted in Malaysia in a large-scale planting program.

Like *A. mangium*, *A. auriculiformis* occurs naturally in Australia, Indonesia, and Papua New Guinea. It was first introduced to Malaysia in 1932 from Thursday Island for use as boundary markers in plantation plots of the Forest Research Institute (Corner 1952; Yap 1987). Now it is commonly found in lowland areas, especially degraded lands such as tin-tailing and BRIS (raised sand beaches) soil.

Acacias for Rural Development

A. auriculiformis is widely planted for fuelwood in rural areas in Bangladesh, India, Indonesia, Pakistan, the Philippines, Nepal, and Thailand (National Research Council 1983; Suttijed 1985). In Malaysia, rubber wood is the more commonly used fuelwood. However, among farmers on the east coast of Peninsular Malaysia, *A. auriculiformis* wood is popular for drying tobacco leaves (Ang and Yusof 1991).

Acacias for Industrial Plantations

Commercial establishment of plantation forests in Malaysia began in 1957 with the planting of *Tectona grandis* in the northern states. In the late 1960's and early 1970's, plantation development in Peninsular Malaysia shifted toward establishment of fast-growing tropical pines. To date, about 6,754 ha have been planted, mainly with *Pinus caribaea* and *Araucaria* species. However, the planting of these species were stopped in the late 1970's due to difficulties in obtaining good quality seeds.

In the early 1980s, the Government of Malaysia embarked on a new reforestation scheme known as the Compensatory Forestry Plantation Project (CFPP). Its main aim is to grow *A. mangium* for sawlog production to meet the timber demand in Peninsular

Malaysia. This will provide a steady source of raw material to the wood-based industries when the supply is depleted. Likewise in Sabah, in East Malaysia, commercial *A. mangium* forest plantations were developed by the state government and semi-private agencies in the early 1980's, mainly for production of pulpwood and reconstituted products.

Presently, in Peninsular Malaysia, the CFPP has established a total of 50,249 ha of *A. mangium* plantation of the targeted 100,000 ha (Table 1). In Sabah, a total of 56,100 ha has been planted with mainly *A. mangium* and other fast-growing species. The Forestry Department is responsible for the development of forest plantations in Peninsular Malaysia, while in Sabah, the Sabah Forestry Development Authority (SAFODA), Sabah Forest Industies (SFI), and Sabah Softwoods Sdn. Bhd. (SSSB) are the three main agencies involved in establishing *A. mangium* plantations.

Table 1. Total area planted with *A. mangium* in Peninsular Malaysia.

Locality	Area (ha)
Johor	18,101
Pahang	16,757
N.Sembilan	3,779
Selangor	8,401
Perak	2,741
Kelantan	270
Terengganu	200
Total	50,249

Thang and Zulkifli (1992) reported that an *A. mangium* plantation in Peninsular Malaysia is expected to yield 21 m^3/ha from thinning at 4-5 years, 60 m^3/ha from thinning at 8-9 years, and 180 m^3/ha at final harvest at 15 years.

Utilization of *A. mangium* Timber

Reconstituted Wood

A. mangium wood has good mechanical and working properties and is quite suitable for low- and medium-density particleboards, medium-density fiberboard (MDF), and cement-bonded particleboard (CBP)(Chew and Jaafar, 1986 and Rahim et al. 1989). According to Meico Chipboard Co. Sdn Bhd., chip/particleboard made with *A. mangium* comforms with the requirements of British Standard of Type 1 board. Tomimura et al. (1987) noted that the properties of MDF of *A. mangium* were superior to those from Japanese softwood chips/mixture.

Veneer

Wong et al. (1988) reported that the decorative panels using *A. mangium* sliced veneers as the face veneers appeared attractive and were found to be suitable for panelling and furniture making. In general, the veneers were smooth and acceptable quality.

Pulp and Paper

A. mangium wood has been found quite suitable for pulp and paper. Peh et al. (1982) reported that sulphate pulping was easy, giving high yields and good strength properties.

Acacias for Environmental Development

Acacia species generally show wide adaptability to a wide range of environmental and soil conditions. In Malaysia, both *A. auriculiformis* and *A. mangium* are suitable for rehabilitating and revegetating difficult sites, such as tin tailings and areas infested by the noxious weed *Imperata cylindrica.* A total of 6,924 ha of *A. mangium* plantation have been established in degraded *Imperata* areas in Bengkoka, Sabah.

A. auriculiformis is widely planted on tin tailings, and is commonly planted in open areas of new housing estates to stabilize slopes as well as for aesthetic value (Zakaria and Kamis 1991).

A. mangium is also used to reclaim compacted sites, including decking and primary logging roads in logged-over forests. Normally these species are planted when logging activities are completed. This has been successfully done in Semangkok F.R., Selangor and Jengka F. R., Pahang.

Conclusion

A. mangium continues to be a very important plantation species in Malaysia. The potential of *A. auriculiformis* for timber and other products, however, has not yet been fully exploited in Malaysia. This species has great potential for wood production and can be easily planted in degraded areas.

Discussion Notes

Q: From your slides, *A. mangium* doesn't appear to do well on sandy soils.

A: At that site, it is due to nutrient deficiency and can be addressed in management. Three types of tin tailings are sand, slime, and mixed. On slime, mangium grows well and appears to nodulate, although growth stops when roots reach liquid slime. Soil amendment testing found organic matter to be the constraint. On slime tailings, mangium performed better than *A. auriculiformis.* On sandy tailings, with their higher temperatures, the species may do more poorly.

Q: Could you provide an update on the status of heart rot on *A. mangium*?

A: In Peninsular Malaysia (PM), 30-90% of plantations appear to be infected, although the volume affected is only about 5% or less. This effect, then, depends on intended end use. In PM, the main planting objective was for sawn timber; in Sabah, for pulp and paper.

In mid-1992, the Minister suspended further *A. mangium* planting unless the objective of the PM plantations was changed to pulp, for which no intensive silviculture is needed. Discussions continue with the private sector and at the Ministry level. (See also the paper by Lee Su See in this volume.)

Q: Has there been a survey of heart rot infection on Sabah?

A: Yes, conducted by Edward Chia for SSSB; but differences in survey methods make comparison with the Peninsular Malaysia survey difficult.

Q: Any conclusion regarding the cause of the heart rot?

A: About 25 fungi may work together to cause the disease. Pruning is one contributing factor, due to the slow recovery of wounds on *A. mangium.*

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Acacias for Rural, Industrial, and Environmental Development in Myanmar

U Saw Kelvin Keh

Introduction

As a country's population increases, there is a greater need for better rural, industrial, and environmental conditions, making the best use of the country's natural and human resources, and cooperating with other countries for scientific and technological exchange and improvement. Better management and utilization of trees can greatly contribute to such improved conditions, especially for countries endowed with large forest areas and a variety of species.

All over the world, foresters and political leaders are awakening to the need to integrate forestry into rural, industrial, and environmental development in new ways. In Myanmar, the government of the United States is working in cooperation with the Government of Myanmar to eradicate poppy production by people along the border with China with replanting of *Acacia auriculiformis*, *A. mangium*, *Eucalyptus camaldulensis*, and some cereals as staple food for the Border Area nationals. Many government ministries and private agencies outside forestry have suddenly become interested in rural development, conservation, and community services.

Utilization of Indigenous Acacias

Although Myanmar is now becoming industrialized in some ways, Myanmar is still basically an agricultural country, with about 80% of the population residing in rural areas and engaged in agriculture. Many peasants in the dry-zone areas earn their living by manufacturing catechu or *cutch* from *A. catechu* Willd. Timber from *A. catechu* is used to make agricultural tools and bows, as well as for fuelwood (particularly the branches) and charcoal. The bark produces a good tannin. *A. arabica* Willd. (known locally as sha) has also been tapped for gum arabic for industrial use for the Burma Pharmaceutical Industry (BPI)(Khin Myo New 1981; Thet Wai 1981).

Other indigenous acacias in Myanmar are *A. leucophloea* Willd. (tanaung), *A. myaingii* Lace. (su-magyi), and *A. microcephala* Grah. (sha-tanaung). They are used for fuelwood and their bark provides tannin. The root of *A. farnesiana* Willd. (nan-lon-kyaing) is also used an aphrodisiac.

Exotic Acacias

Trial plantings of *A. auriculiformis* have been carried out in the dry zone by the Forest Research Institute in Yezin (Gyi 1991). The objective was to identify a fast-growing fuelwood species that can establish in adverse arid conditions and meet the needs of the local population for scarce fuelwood. The results are not very promising, possibly due to the aridity and/or poor soil of the trial site. Still, the species is extensively and successfully planted in urban and other rural areas of the country, where people greatly appreciate its fast growth, year-round greenness, shade and shelter for humans and livestock, soil rehabilitation, and good fuelwood and charcoal. It is also successfully used in the Frontier Areas Development, as well as in national development, to provide these products and uses on otherwise unproductive sites. The flowers of *A. auriculiformis* are readily bought by urban and local people for use as altar flowers. The flowers resemble those of *Pterocarpus macrocarpus, P. indica*, and *P. dalbergoides*, which are local favorites for offerings. Edible fungi can also be grown on the species' wood (NFTA 1987).

Acacia mangium is also planted in Myanmar, both for ornamental and aesthetic purposes in urban areas. *A. auriculiformis* hybridizes naturally with *A. mangium*, and there is great potential to exploit the vigor of the hybrid in the near future.

Gum arabic has also been tapped and analyzed from trial plantations of imported *A. senegal* (L.) Willd. The gum quality from Senegal sha meets the U.S. Pharmacopeia (USP) specifications (Aung 1987, 1992), and is suitable for other industrial uses, such as confectioneries, dairy products, baked goods, flavor fixatives and emulsification, beverages, medicines, cosmetics, adhesives, paints, inks, lithography, and textiles.

Environmental Factors

There are indications of health hazards caused by large-scale planting of *A. auriculiformis* in urban areas. In Yezin, in the semi-arid region, the area is seemingly flooded with *A. auriculformis* plantings, as Yezin residents prefer the species above all others. After seven or eight years, however, instances of asthma have increased considerably. Pollen counts in the area show that 80-85% of the pollen are from *A. auriculiformis*. When the pollen is breathed into the human trachea, they adhere to the mucus there and cause throat irritation and repeated coughing, and can ultimately lead to asthma in susceptible individuals.

Policies Related to Tree Growing

As part of the National Plan for combatting the country's acute fuelwood shortage, the Government has recently abolished the 1902 Burma Forest Act and replaced it with a New Forest Act, which permits local peasants and farmers to "possess" forest land adjoining their villages on a long-term lease. They can plant or cultivate any kind of plant or tree, although preference is given to fast-growing fuelwood species. They can freely market the produce after paying a revenue fixed by the Government.

Conclusion

Possibilities are bright for further extensive planting and use of *A. auriculiformis* and *A. senegal* for rural, industrial, and environmental development in Myanmar. Further research should test and explore the vigor of the hybrid cross between *A. auriculiformis* and *A. mangium*.

Discussion Notes

Q: Regarding sale of *A. auriculiformis* flowers, are they sold in branches?

A: Yes, in the same way as *P. indica* for which it substitutes.

Q: Where are *A. arabica* and *A. senegal* grown in Myanmar?

A: In the north near the Chinese border, using seed sources from Yezin.

Q: Have acacia plantations been established?

A: Not yet, as research is still at the field trial stage.

Q: Can you offer any estimate on the extent of cottage industries using acacias?

A: No data are available, but communities in the drier areas in central Myanmar use *A. catechu* for tannin and fuelwood.

Q: There is a weed common to areas of India and Myanmar, *Eupadorium odoratum*—how do acacias in Myanmar respond?

A: In the North, there is no problem. In other areas (for example, the southwest) it can be a problem.

Q: Is the use of gum arabic you mentioned significant economically?

A: It is used mainly in the pharmaceutical industry, and locally grown trees supplement amounts imported for that use.

Q: Is gum obtained from *A. catechu*?

A: No.

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Acacias for Rural, Industrial, and Environmental Development in Nepal

Jay B.S. Karki and Madhav Karki

Introduction

The rapid decline in Nepal's forest resources over the last four decades, especially in the Tarai and Inner Tarai regions where they have been overexploited to meet basic needs of fuelwood and fodder, has raised serious social, economic, and environmental concerns (Karki and Pokhrel, in preparation; Wallace 1988). Poor government forest policy, population pressure, human neglect, and inappropriate development interventions have resulted in the gross misuse of natural forests (Karki 1992a).

The emphasis on agricultural development has been primarily based on the unsustainable conversion of forest land to crop land (LRMP 1987, Mahat 1987). Yields of major food crops have either declined or stagnated at levels attained in the early 1960s (APROSC 1986). One reason for this decline is the widespread use of cow dung cake as domestic fuel instead of its traditional use as soil improver for Tarai soils. The increase in arable land through forest clearing has so far allowed the country to meet its food production needs. However, no more significant forests remain for such agricultural expansion. Total forest area is estimated to be 37% of the total land area, but most of that is degraded (LRMP 1987; Nield 1985; Wallace 1988). The carrying capacity of the resource base—especially in the Hills, where up to 16 people depend on a single hectare of arable land—is no longer able to keep up with the requirements of the rapidly growing population.

Forests and forest products play an important role in supporting agriculture in the hills, industrial development in the urban areas, and environmental harmony throughout the country (Karki 1983; Karki 1989; Karki 1992b). Fuelwood, timber, fodder, and leaf litter are the most important forest products required by the rural people. Forests also provide a vital environmental service by stabilizing the fragile hilly slopes and also affording watershed protection functions. Afforestation programs favor native species over exotics due to their low vulnerability to diseases and proven adaptability to the diverse ecosystem. In Nepal, a few native species have dominated plantation and agroforestry programs: *Dalbergia sissoo, Pinus roxburghii, Eucalyptus camaldulensis,* and a few fodder species. Acacias have so far failed to attract the attention of foresters, technicians, and farmers. Still, most acacias are known to produce good firewood and some also are used as excellent fodder and therefore have the potential to become a viable tree component of Nepal's complex farming systems for these products as well as shade, shelter, bedding material, and soil improvement. Acacias also fix nitrogen, and many of them grow quickly.

Of a number of indigenous acacias, only *A. catechu* (*Khayer*) is socioeconomically, environmentally, and commercially important in Nepal. It is native to the riverain ecosystem of the Tarai and the Inner Tarai and is found at elevations up to 900 m. Rural communities use it for fuelwood, small timber, and fodder; and both urban and rural people use the *katha* (masticatory) and *cutch* (tanning and lubrication) made from it. Foresters and soil conservation workers are increasingly using this species to stabilize fragile, hilly slopes. Although there are several provenances, no systematic evaluation has been carried out to compare them with exotic species. However, provenance evaluation of different Australian acacias has been carried out, resulting in a short list of potential species.

Acacia Research in Nepal

Research conducted in Nepal has been provenance evaluation trials. A systematic provenance trial of exotic acacias began in the late 1970s (Joshi and Wyatt-Smith 1982) with *A. baileyana, A. flavescens, A. mearnsii, A. pendula,* and *A. victoriae*. Only *A. mearnsii* showed promise in the Kathmandu Valley (Joshi and Wyatt-Smith 1982). Trials conducted by the Forestry Research Project and by the IDRC-funded Farm Forestry Project (FFP) in the Bhabar Tarai and Inner Tarai regions tested *A. aneura, A. auriculiformis, A. crassicarpa, A. dealbata, A. decurrens, A. mangium, A. pendula,* and *A. polystacha* (Neil 1990; FFP 1988). Table 1 shows the results.

A. auriculiformis shows the best overall survival rates among exotic acacias (Figure 1). Although it is a poor fodder, it provides fuelwood, soil conservation, and other uses. It is known to have some allelopathic effects on the germination properties of agroforestry crops (Neil 1990) but so far no serious problems have been reported. In a green manure evaluation trial involving three acacias, *Acacia dealbata* gave the best results with corn yield of 1.06 ton/ha followed by *Acacia auriculiformis* (0.8 ton/ha) (FFP 1988). *Acacia crassicarpa* gave nearly the same result (0.77 t./ha).

Acacia crassicarpa showed the best growth at sites in the Tarai, reaching a height of 4.5 m. in one and half years at one site. *Acacia catechu* is the slowest of the prominent acacia species, but because it is native to the area it is much more widely found and used than the others.

Acacia nilotica (babul), which may be indigenous to Nepal, has performed poorly in trials at Adabhar (central Nepal) by the Forest Research Division and at Butwal and Dang (western Nepal) by collaborating researchers in the Multipurpose Tree Species Research Network. At 15 years of age, the mean height was only 17.4 m and survival was only 56% (Table 2). Still, further research should evaluate other provenances in other ecological zones. Good growth has been observed on farms and homesteads at site near Bhairahawa in western Tarai, where this species is known to grow naturally. Farmers there report that they collect seedlings from beneath mother trees and transplant them. Farmers also allow this species to grow anywhere it appears on farm land; *A. nilotica* trees are often protected in rice fields, where few other tree species are permitted. Table 2 shows growth information from a typical village site in western Nepal.

Table 1. Performance of promising acacias at four sites in Nepal.

Species	CSIRO No.	Age	Survival (%)	Mean Ht. (m)
Adabhar (Bhabar Tarai, 250 m asl)				
A. auriculiformis	15477	1.6	70	3.5
A. auriculiformis	13191	1.6	60	3.8
A. crassicarpa	15283	1.6	56	3.6
A. leptocarpa	14966	1.6	24	3.1
A. crassicarpa	13681	1.6	48	4.5
Panchkhal (Lower Middle Mountains, 1000 m)				
A. auriculiformis	15477	2.5	83	1.4
A. crassiocarpa	15283	2.5	70	1.0
A. torulosa	14183	2.5	63	1.4
A. tumida	14661	2.5	66	1.2
A. auriculiformis	15477	2.5	81	0.9
A. brassii	15480	2.5	84	0.8
A. crassicarpa	15283	2.5	84	0.4
A. difficilis	14619	1.5	59	0.6
A. holosericea	13879	1.5	78	0.6
A. leptocarpa	14966	1.5	90	0.8
A. pellita	17068	1.5	87	0.7
A. shirleyi	14622	1.5	53	0.5
Thulo Sirubari (middle mountains, 1400 m)				
A. adunca		2.6	50	1.2
A. deanii		2.6	72	0.8
A. fimbrita	14736	2.6	50	1.0
A. podalyriifolia		2.6	67	2.3
A. aulacocarpa	13865	0.6	54	0.2
A. auriculiformis	15477	0.6	87	0.3
A. brassii	15480	0.6	66	0.1
A. crassicarpa	15283	0.6	66	0.1
A. difficilis	14619	0.6	54	0.2
A. holosericea	13879	0.6	100	0.2
A. irrorata	17145	0.6	66	0.4
A. leptocarpa	14966	0.6	87	0.2
A. melanoxylon	14766	0.6	74	0.5
A neriifolia	14735	0.6	62	0.4
A. pellita	17068	0.6	66	0.1
A. simsii	14862	0.6	54	0.1
A. stenophylla	14670	0.6	95	0.5

Table 1 continued.

Species	CSIRO No.	Age	Survival (%)	Mean Ht. (m)
Kadambas (middle mountains, 1600m)				
A. holosericea	13771	1.5	65	0.5
A. melanoxylon	14766	1.5	70	0.6
Syaule (middle mountains, 2050)				
A. dealbata .	17123	1.5	89	1.0
A. falciformis	15502	1.5	53	0.5
A. filicifolia	14990	1.5	77	0.9
A. mearnsii	14771	1.5	75	0.5
A. dealbata	14772	1.5	91	0.8

Table 2. *Acacia nilotica* growth at Moti Pur farm site, near Bhairahawa.

Age	dbh (cm)	Height (m)
5	7.0	7.0
10	14.0	14.1
15	16.5	17.0

Source: Data collected as reported by farmers

More recently, donor-funded projects have included acacias in agroforestry and farm forestry plantations. Out of several species tested *A. auriculiformis* and *A. mangium* have shown comparable performances. Table 3 and Figure 2 show performance reported by the IDRC-funded FFP at its various Tarai locations.

Acacias and Rural Development

In Nepal, "rural development" essentially means development of the agriculture and forestry sectors to increase the production capacity of rural resources. Rural Nepal today faces acute shortages of fodder, fuelwood, composting materials, and timber. Acacias can play an important role in sustaining soil fertility and thereby increasing agricultural productivity. In particular, acacias have potential to meet the needs of rural farmers and artisans for:

1. fuelwood with high calorific value that can substitute for farmyard manure and increase agricultural productivity
2. straight-stemmed timber good for poles and lumber
3. raw materials for paper and pulp industries
4. soil and water conservation on poor sites (sloping areas and degraded riversides)

Fodder

Among acacias tested in Nepal, *A. auriculiformis* has shown the best potential for production of woody as well as leafy biomass. A study

Table 3. Performance of eight-year old acacias at FFP sites, with other popular species.

	A. auriculiformis		*E. camaldulensis*		*D. Sissoo*		*L. leucocephala*	
	dbh (cm)	Ht. (m)	dbh (cm)	Ht. (m)	dbh (cm)	Ht. (m)	dbh (cm)	Ht. (m)
Tamagarhi	18.5	9.8	16.1	12.4	12.6	8.6	13.4	11.6
Rampur	13.6	7.6	21.5	12.6	20.5	8.4	11.5	12.4
Pokhara	9.6	6.5	11.5	7.6	16.4	7.6	14.4	9.8
Average	13.9	8.0	16.3	10.8	16.5	8.2	13.1	11.2

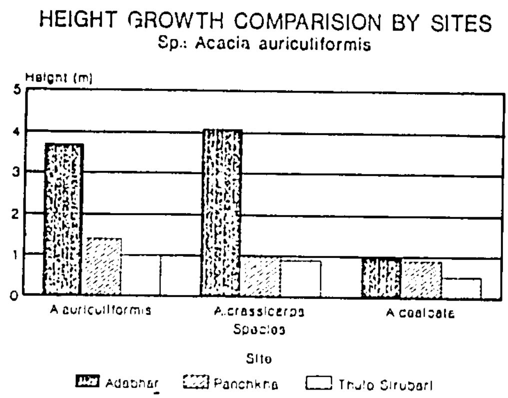

Figure 1. Height growth comparison of three acacias at three sites (1988 data).

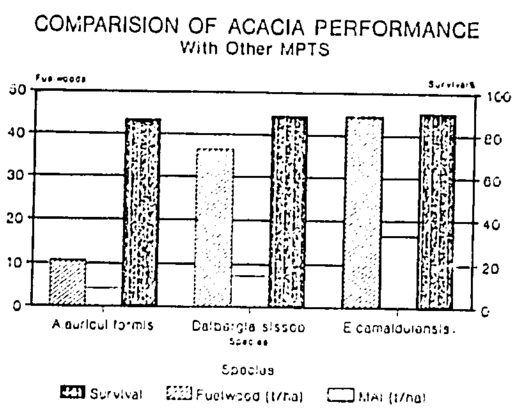

Figure 2. Comparison of acacia performance with other MPTS (1988 data).

Table 4. Nutrient contents (%) of different acacias in Nepal.

Species	Calcium	Moisture	CP	Ether extract	Acid-insoluble ash	Crude fiber
A. auriculiformis	11.8	19.4	4.05	0.06	20.2	0.50
A. catechu	8.4	14.4	5.2	0.8	13.1	1.50
A. crassicarpa	8.0	16.3	6.16	0.20	27.1	0.55

conducted by FFP shows that a 4.5-year-old *A. auriculiformis* plantation with an average height of 6.8 m can produce 226 kg of green biomass (FFP 1988). Table 4 shows the fodder nutrient analysis of three acacias' foliage.

Fuelwood

The fuelwood situation continues to worsen. Nepal as a whole faces both fuelwood and timber deficits; fodder is said to be relatively more abundant (Table 5).

Acacias and the Environment

Nepal's current forest development approach is basically oriented to meeting community needs, but an additional focus should be placed on improving the deteriorating environment, especially in the hills and mountains. A major constraint in reforesting the degraded hills in Nepal is the lack of a range of species that can grow on problem sites. In such sites, species selection is often decided by local people. Traditionally, villagers have grown slower-growing

Table 5. Supply and demand for forestry products in Nepal.

Item		1985-86	1990-91	2000-01	2010-11
Fuelwood	Supply	9.2	9.7	12.1	15.5
(m tons)	Demand	11.3	12.6	15.2	16.9
	Balance	-2.1	-2.9	-3.1	-1.4
Timber	Supply	0.9	1.0	1.4	2.2
(m m^3)	Demand	1.1	1.5	2.5	3.3
	Balance	-0.2	-0.5	-0.5	-1.1
Fodder	Supply	6.6	6.7	7.4	8.3
(m tons)	Demand	6.1	6.4	7.2	8.5
	Balance	+0.5	+0.3	+0.2	-0.2
Forest area required		25.9	158.8	741.3	1464.6

Source: MPFS (1988)

native species.

However, fast-growing species are increasingly in demand. *Leucaena leucocephala* became popular mainly due to its ability to grow fast and produce multiple products, but with that species' infestation with *Heteropsylla cubana* (leucaena psyllid), farmers and foresters have looked for alternative species, without much success. *Dalbergia sissoo* and *Eucalyptus camaldulensis* are also popularly grown. Acacias, with their precocious seed production and proven ability to grow on problem sites, have potential to supplement these planting options (Figure 3, Table 6).

Acacias and Industrial Development

Forest industries in Nepal are not well developed. Most of the traditional industries are timber based. However, many new industries have recently been set up for producing pulp and paper, plywood, cutch, resin, and turpentine. These industries lack adequate raw materials, particularly the pulp, paper, and plywood industries. The endemic fuelwood shortage affects industrial ventures by diverting raw materials to meet domestic energy demands. Several industries have looked into the feasibility of using *A. auriculiformis* to meet their raw material needs. *A. catechu*, a traditional raw material for cutch, paint and tannin products, is always in very high demand; many logs are illegally smuggled to India. The practice of harvesting this species at a young age is placing it under severe pressure and disrupting its natural regeneration.

Recommendations for Research

Regarding indigenous *A. catechu*, studies should be directed at improving its regeneration and utilization. Currently, farmers use it only for fodder and timber, but it is also very valuable in the katha and cutch industries. Studies on improved marketing and utilization strategies would help improve farm household earnings.

Based on results obtained so far, the following exotic acacias show strong potential: *A. auriculiformis, A. dealbata, A. holosericea, A. mearnsii*, and *A. podalyrifolia*. *A. auriculiformis, A. crassicarpa*, and *A. holosericea* are specifically recommended for the Tarai and Inner Tarai regions. *A. dealbata, A. mearnsii, A. podalyriifolia, A. holosericea*, and *A. decurrens* are suggested for the middle hills and mountains. *A. auriculiformis* is already widely planted in the Tarai, Inner Tarai, and Midhills. Appropriate provenance selection continues, but is constrained by the scarcity of good quality seeds. Most seeds are imported from India and have a limited genetic base. Sources in Hawaii and Australia are recommended but growers in Nepal find the high costs of these sources prohibitively expensive.

Research on silviculture, management, and utilization of these exotic acacias will be increasingly important with the rising demand for agroforestry and environmental plantations. Suitable silvicultural and management prescriptions for alley cropping and farm forestry are urgently needed. For *A. auriculiformis*, studies in Nepal are needed on its dieback and stunting problems. One hypothesis emerging from plantation studies in the mid-hills is that this species is sensitive to

Table 6. Comparison of *Acacia auriculiformis, Eucalyptus camaldulensis*, and indigenous *Dalbergia sissoo* for fuelwood.

	Sagarnath						Adabhar						Chitrepani					
Species	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
A. auriculiformis	2.5	1,250	87	10.6	4.2	--	--	--	--	--	--	--	5.5	1,600	100	4.1	3.5	--
Dalbergia sissoo	5.0	1,600	89	36.6	7.3	11.8	1.5	2,500	99	5.2	3.5	--	---	---	---	---	---	--
E. camaldulensis	3.35	1,425	91	44.6	16.5	25.4	1.5	6,250	97	15.1	10.5	--	---	---	---	---	---	--

1 = Age; 2 = Initial Stocking; 3 = Survival %; 4 = Total Fuelwood (tons/ha); 5 = Fuelwood MAI (tons/ha); 6 = OB Volume MAI (m^3/ha/yr).

a calcium layer in the C horizon, as well as to nitrogen deficiency.

Finally, multi-location on-station and on-farm trials involving both native and exotic species is recommended as a first step towards expanding acacia plantation in Nepal.

Discussion Notes

Q: Regarding your comparison showing *Dalbergia sissoo*'s and *Eucalyptus camaldulensis* outperforming *A. auriculiformis*, is there still a place for that acacia in Nepal? What is the response of farmers to acacia planting?

A: Yes, these results are short-term and long-term research continues to be needed. Furthermore, eucalyptus has different site requirements than *A. auriculiformis* that may make the latter species better adapted on some sites. Regarding your second question, farmers still prefer indigenous species for fodder and fuelwood.

Q: Have there been fodder tests of these acacias?

A: *A. auriculiformis, A. catechu*, and *A. crassicarpa* have been tested but not yet in an on-farm situation.

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Acacias for Rural, Industrial, and Environmental Development in Pakistan

Raziuddin Ansari, A.N. Khanzada and M.A. Khan

Introduction

Only 3.2% of Pakistan's total land area of about 80 million ha is under forest cover. Continuous efforts and massive campaigns are launched each year to plant more trees, and the forest departments in the country's four provinces distribute seedlings at low cost; these measures help to maintain the area under forest at a constant level, but the situation needs improvement.

Pakistan's climate varies from the mild to very hot (temperature often reaching 45°C) coastal areas to the northern hilly areas where temperatures dip below freezing. The vegetation varies accordingly (Table 1). Coniferous forests prevail in northern and other cool areas, the coast is dominated by mangroves, and the drier areas generally have range lands and scrub vegetation (Anon. 1988). Tree planting is restricted to riverain forests and irrigated

Table 1. Vegetation types in the provinces of Pakistan (thousands of ha).

	Punjab	Sind	NWFP	Balochistan	Total
Coniferous	25	–	1105	131	1261
Irrigated plantation	136	82	--	–	218
Riverain	54	241	–	5	300
Shrub	302	10	115	142	569
Coastal	–	345	–	--	345
Mazri lands	–	–	24	--	24
Linear Planting	–	–	159	--	159
Range lands	2723	489	150	787	414
Total	3240	1167	1553	1065	7025
Protected areas	2726	862	617	378	4583
Net area under forests	514	305	936	687	2442
Area under fruit cultivation	280	81	25	42	428
Total tree cover	794	386	961	729	2870

Source: Anon. (1988)

plantations, where acacias form an important component.

Classification and Distribution

Acacias belong to the family Leguminosae, one of the three largest families of angiosperms. *Acacia* is the largest genus in the subfamily Mimosoideae. Acacias are mostly trees, many of which are xerophytes found in Southern Africa, Central and Southern America, Australia, South and South East Asia (Lawerence 1964; Rendle 1959).

Nasir et al. (1972) record some 25 indigenous and exotic species of *Acacia* in various parts of Pakistan (Table 2). The most popular species among these is *A. nilotica*; its ssp. *nilotica*, *indica*, and *cupressiformis* are widely scattered. Because the species withstands extremes of temperature (-1 to 50°C, although frost-sensitive when young), it occurs from sea level to over 500 m and is found in nearly all parts of Pakistan from Karachi to Peshawar. It is very thorny, has bright yellow flowers and dark indehiscent pods. Flowering is profuse and may occur repeatedly in a season, but seed set is very poor, only about 0.1% (Tybirk 1989).

Hurries, Traditional Block Plantations of *A. nilotica*

The popular practice of farmers planting *A. nilotica*, particularly in Sind province, dates back to 1858 when farmers were provided land free of charge for block plantation of *A. nilotica*, with none of the taxes normally levied on agricultural lands. The practice, known as "Hurries," is still strong in Hyderabad Division, where it accounts for about 10,000 ha of the estimated total of 36,000 ha of *A. nilotica* plantation (Sangi 1987).

The cost:benefit ratio with hurries has been calculated at 1:1.72, compared to 1:1.52 for most agricultural crops. For self-employed hurries farmers who can save on labor costs and have access to their own seed source, this ratio may be even better (Wagan 1989). Hurries usually occupy marginal lands as part of a rotatioal fallow system with agricultural crops, often cotton. In the last year of the cotton (or other) crop, *A. nilotica* seed is scattered over the plot amid the cotton and receives an initial irrigation. After that, it receives only runoff from adjoining plots. The thick tree cover is thinned to a tree spacing of about 1 m apart. Still tightly spaced, the trees grow for 5-6 years and are then harvested and sold at a reasonable price for mine props, with roots sold for charcoal production. The cleared land is then returned to agriculture for the next few years.

With systematic rotation of trees and crops, an intelligent farmer can maintain the productivity of his entire land for better production of annual crops with minimum inputs. The trees not only meet his fuelwood and fodder needs, but also provide insurance against emergencies, representing capital to fall back upon in times of need or in a year of bad harvest. Considering these benefits, incentives should be provided to make hurries more widespread.

Uses of *A. nilotica*

Every part of *A. nilotica* trees from roots to crown is useful in some way. In summer, the trees provide shelter and serves as an effective fence, protecting

Table 2. *Acacia* species found in Pakistan.

Species (Synonym)	Origin	Distribution in Pakistan
Acacia aneura	Australia	Cultivated in gardens
A. auriculiformis	Australia	Cultivated in gardens
A. catechu (*Mimosa catechu*)	–	Scattered on foothills up to 4000' Peshawar, Rawalpindi, Swat
A. cornigera (*A. spadicigera, Mimosa cornigera*)	Mexico	Lahore
A. decurrens	E. Australia, Tasmania	var. *decurrens* - Abbotabad; var. *mollis* - Muzaffarabad
A. ebrunea (*Mimosa eburnea*)	–	Sind, Salt range, Punjab
A. farnesiana (*Mimosa farnesiana*)	Tropical America	Plains and hills upto 4000'
A. filicina, A. filicioides	Tropical America	Lahore
A. gageana	–	Jammu, Some parts of Pakistan
A. homalophylla	Australia	Gardens
A. hydaspica	–	Peshawar, Jhelum, Rawalpindi, Turbat
A. jacquemontii	–	Sind, Punjab, Balochistan
A. leucophloea (*Mimosa leucophloea*)	--	Nagar Parker hills, Punjab
A. mearnsii	Australia	Hazara
A. melanoxylon	Australia	Gardens
A. mellifera (*Mimosa mellifera*)	Africa, Arabia	D. I. Khan
A. modesta	–	Dir, Swat, Jhelum, Salt range
A. nilotica (*Mimosa nilotica, M. arabica, Acacia arabica*)		
ssp. *nilotica*	Sahelian Africa	Scattered
ssp. *hemispherica*	–	Karachi, near coast Paradise Point
ssp. *cupressiformis* (*A. arabica* var. *cupressiformis*)	--	Punjab, Sind
ssp. *indica* (*A. arabica* var. *indica*)	--	Lyallpur, Jhelum, Lahore, Hala forest, Jamshoro, Thatta, Gharo
ssp. *astringen* (ssp. *adansonii*)	–	Karachi, Malir, Kotri, Ghulamullah, Gharo, Thatta
ssp. *subalata* (*A. subalata*)	–	Karachi
A. saligna (*Mimosa saligna*)	S.W. Australia	Rawalpindi, Peshawar
A. senegal (*M. senegal*)	–	Karachi, Dadu, Sukkur, Tharparkar
A. seyal (*Acacia fistula*)	Africa	var. *seyal* and *fistula*- D.I.Khan
A. sieberana	Africa	D.I. Khan
A. sphaerocephala, A.veracruzensis	Mexico	Lahore
A. torta (*Mimosa torta*)	–	Kotri, Jammu
A. tortilis (*Mimosa tortilis*)	N. Africa, Arabia	Changa-Manga, Lahore

Source: Nasir et al. (1972)

crops from livestock as well as dessicating winds. Because of its narrow crown, the subspecies *cupressiformis* is becoming a more popular wind break than other varieties.

Land Rehabilitation

A. nilotica tolerates saline and sodic soils and helps maintain vegetative cover on these areas. Its tap roots open the soil and improve leaching of nutrients, while litter fall adds organic matter. The fixation of atmospheric nitrogen further improves fertility. Ongoing research at the Atomic Energy Agricultural Research Centre (AEARC) is studying these aspects.

Wood

The dark brown wood is nearly twice as hard as teak, durable, and shock resistant. It is used as poles, posts, mine props, railway sleepers, and tool handles. It is an excellent fuelwood (a scarce commodity in Pakistan's rural areas) with a high calorific value of 4,950 kcal/kg (Fagg 1992).

Fodder

Cattle relish twigs and pods of *A. nilotica*, and goats are particularly expert at picking the leaves from the thorny branches. Pods are a rich source of protein, and so provide an easy means, generally practiced by farmers, of obtaining seed for sowing from the animal dung in pens (Sheikh 1989). Seeds collected in this way need no further pretreatment.

Industrial Uses

The hard, fine-textured, tough wood is resistant to termites and impervious to water. It is hence ideal for furniture, boat building, oars, carts, and is good for carving and turning.

It is an important source of shellac and gum arabic, with properties similar to the gum now obtained from *A. senegal*. The gum is used to manufacture matches, inks, paints, and confectionery. The bark and pods are widely used in the leather industry, with tannin content varying from 12-20%. Honey is a valuable by-product from the plantations.

The charcoal-making sector relies mainly on *A. nilotica*, using not only the portion of the tree above-ground but also roots and stumps, as mentioned above. The charcoal burns slowly with intense heat and little smoke.

Other Acacias of Interest

In an effort to make the large tracts of saline waste lands throughout Pakistan productive for farmers by use of trees, a number of Australian acacias have been introduced in Pakistan in the past five years. These efforts are at present restricted to AEARC in Tandojam, the Punjab Forest Research Institute in Faisalabad, the Nuclear Institute for Agriculture and Biology in Lahore, and the Pakistan Forest Institute in Peshawar. Among the species tested at Tandojam (Table 3), *A. ampliceps*, *A. stenophylla*, and *A. machanochieana* show potential. Species being tested at Peshawar on a limited scale for salinity and/or drought tolerance include: *A. tortilis*, *A. radiana*, *A. aneura*, *A. cyclops*, *A. sclerosperma*, *A. albida*, *A. modesta*, and *A. adsurgens* (Hussain 1991; Sheikh and Shah 1983; Sheikh, personal communication). Some of these species are also under trial at

Table 3. Growth of *Acacia* species on highly saline soil at 9, 12, and 15 months at Tandojam.

Species	9 months		12 months			15 months			
	Survival (%)	Height (cm)	Survival (%)	Ht. (cm)	Basal diameter	Survival (%)	Height (cm)	Basal diameter	DBH (cm)
A. ampliceps									
(14668)	33	110	32	148	3.63	33	162	4.58	3.52
(15741)	39	152	39	188	4.94	39	211	5.91	3.75
(15769)	33	79	33	102	2.67	32	122	3.23	2.20
(15734)	32	116	32	148	3.93	32	169	4.91	2.84
A. machonochieana									
(14676)	23	97	22	116	2.34	21	124	2.65	1.05
A. stenophylla									
(14670)	15	102	16	119	2.12	16	139	2.37	1.48
(15736)	26	142	26	169	2.62	26	189	3.83	1.83
A. auriculiformis (16484)	-	-	-	-	-	-	-	-	-
A. salicina (16648)	-	-	-	-	-	-	-	-	-
A. victoriae (17209)	11	96	10	129	2.17	10	135	2.52	1.55
A. nilotica	11	56	5	57	0.68	4	161	3.91	2.96

Source: Ansari et al. (1992)

Lahore under saline but more sodic conditions than at Tandojam (Islam, personal communication).

Research Needed on Acacias in General, and *A. nilotica* in Particular

1. Provenance selection for suitability in a range of environments
2. Seed orchard establishment for production of uniform, good-quality seed
3. Determination of optimum nursery techniques
4. Nutrition/fertilizar studies
5. Studies of rhizobia and mycorrhizal relationships
6. Cultural practices (spacing, pruning, pollarding)

7. Breeding for better characteristics

Concluding Remarks

With more than 70% of Pakistan's population in rural areas and a meager forest cover, farming and forestry are still often viewed as separate activities. Boundaries between agricultural scientists and foresters are clearly marked and trespassing is not viewed favorably. This is unfortunate, as "like the separation of husband and wife, it creates many more problems than it solves" (Evans 1988). These views are changing but much remains to be done.

Farmers of annual crops may not be interested in exclusive tree cover except where land has degraded to a point where planting agricultural crops is no longer viable. But there is definitely a need for having trees side-by-side with crops.

Because acacias dominate the riverain and irrigated plantations, they can play a major role in these situations. Many industries depend on wood, but local production falls short of demand. In 1986-87, Pakistan produced 950,000 m^3 of timber and firewood (valued at 887 million rupees) but spent 2.388 billion rupees (Table 4) on imports of wood and wood manufacturing material (Anonymous 1988).

Table 4. Wood production and imports in Pakistan.

Product	Qty. (000s m^3)	Value (millions Rps)
Domestic production*		
Timber	407	810.0
Firewood	543	77.0
Total	950	887.0
Imports of wood and wood products**		
Timber (round and saw)		142.4
Wood and wood manufacture (Veneer, plywood, etc.)		17.8
Pulp and paper board		2164.0
Miscellaneous items (Resin, Cork, Bamboos etc.)		64.6
Total		2388.8

*1986-87;**1987-88 *Source:* Anon. (1988)

Imports are generally more costly and involve more bottlenecks than local supplies. A steady supply from local sources would benefit the relevant industries, but the ultimate beneficiary would be the farmer, on whose welfare depends rural prosperity and in turn the country's development.

Discussion Notes

Q: Hurries depend on irrigation, and the seed used in them is still unclassified. How will these situations be improved in the future?

A: These topics need work; there is a large degree of variability within a single seed source, as you note.

Q: It is interesting to note the whole-tree concept of utilization for *A. nilotica* as you have presented. Regarding its use as fodder, are there available comparisons?

A: Such studies are now underway with Australian support, comparing different species and their suitability as fodder for sheep, goats, or buffalo.

Q: Has *A. holosericea* been tested?

A: No, it was not received among the seedlots from CSIRO to be tested.

Q: There would appear to be no significant difference between cost-benefit returns of *A. nilotica* and those of agricultural crops. Why then would a farmer grow the trees, which take longer before this return is realized?

A: Your analysis is right; tree planting in mixed agroforestry systems therefore may be a more suitable planting system. In the case of hurries, though, the tree crop does not replace an agricultural crop, but is used as a fallow improvement crop for 4-5 years.

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Update on Acacias in Papua New Guinea

P.B.L. Srivastava

In view of the recent summaries included in the proceedings of last year's COGREDA meeting (Srivastava and Yelu 1992) and in the forthcoming proceedings of the national MPTS research meeting held in Lae in 1992, this presentation will not recapitulate that information.

Given the large number of acacias native to Papua New Guinea, one can see why Papua New Guinea (PNG) is a main seed source for acacias, particularly provenances of *A. auriculiformis, A. aulacocarpa,* and *A. mangium.*

Rural Development

Only *A. mangium* has shown some potential for local use in PNG. As an agroforestry crop, it is still on a trial basis. A principal constraint to acacias' wider use in this way is the lack of market-oriented farms—most PNG farmers are small gardens, in which traditionally grown species (for example *Casuarina oligodon* in the highlands) are preferred.

Industry

Two companies are active in forest plantation in PNG: Japan New Guinea Timber Pty. Ltd. and Stettin Bay Lumber Co. While *Eucalyptus deglupta* is native and well-researched, *A. mangium* appears better, with 90% incidence of single stems. As a result, both companies are replacing *E. deglupta* with *A. mangium* in their new planting efforts.

Environment

The only serious environmental problem in PNG is the reclamation of former mining areas; PNG is the world's fourth largest producer of tin. Two trials of acacias on tin tailings are assessing their promise for this purpose in PNG.

Discussion Notes

Q: What seed production areas are active in PNG presently?

A: Seed production areas established in PNG began to yield seed in the last 2-3 years. Each of the several sites is 2-5 ha.

Q: PNG is rich in forest resources; why does it plant acacias?

A: Because the two companies active in the country have already logged their concessions of natural forest, the Government requires them to maintain that land through reforestation.

Q: Of the 2 million m^3 harvested annually in PNG, how much is acacia?

A: So far, almost nil. Acacia harvests began only three years ago. But by 1997, all wood harvested will come from plantations. Landowners now find sales of seed more profitable than timber.

Q: Have studies compared the wood production of acacias with that of *Leucaena leucocephala*?

A: No, since leucaena is grown mainly as a shade crop.

Comment: Recently in PNG there has been evidence of *A. mangium* heart rot, as in Malaysia. Since its main use is for chipping, however, this appears to cause little concern.

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Experience with Acacias in Sri Lanka

K. Vivekanandan

Introduction

Acacias are as important as eucalypts in the plantation forestry of Sri Lanka, and during the pioneering years these two genera featured prominently in upland planting programs. Australian acacias were first introduced to Sri Lanka in the late 1860's. Initially, *Acacia decurrens* and *Acacia melanoxylon* were introduced for use as windbreaks, fuelwood plantings, and as ornamentals. Later, *A. dealbata* and *A. mearnsii* and others were introduced.

The main purpose of planting acacias in the uplands was to produce fuelwood for the tea industry and the railway. In 1915 the Forest Department embarked on large-scale planting of eucalypts and acacias to meet the increasing demand for firewood. These two species were planted as mixtures, with *A. decurrens* planted under *Eucalyptus*. In 1928, the pace of planting slowed as the railway switched to coal for its energy needs. *A. mearnsii* was planted for production of tannin, an industry which flourished in the 1880s but which was gradually phased out due to increasing production costs.

Since 1980, the Forest Department has conducted field trials with several Australian acacias. This experience is summarized below. In addition to these exotics, four acacias grow naturally in the dry zone of Sri Lanka: *A. ebrunea, A. leucophloea, A. planiformis,* and *A. sundra. A. ebrunea* is used as fuelwood. *A. leucophloea* shows good growth on saline sites. In 1989-1990, Sri Lanka embarked on trials with *Acacia senegal,* mainly for gum production.

Experience Before 1980

Acacia decurrens

From its introduction by tea planters, this species has a long history in Sri Lanka, and is widely used above 1000 m as hedges, shelterbelts, shade trees, green manure, and fuelwood. Early experience with its rapid growth and abilities to grow in poor soils and tolerate grass competition (8 m in 1.5 years, 12 m in 4 years) encouraged wide cultivation of the species for fuelwood. It was a major component of government fuelwood plantations until 1936, when plantation activities above 1500 m elevation were stopped (Streets 1962; Champion 1935). Streets (1962) recorded a fuelwood production of 378 m^3/ha at year 15.

As a source of tannin, the species is second only to *A. mearnsii*, which grows more slowly but is higher-yielding. Macmillan (1914) records a yield of 7.9 t tanning bark/ha after 8 years at a spacing of about 4 x 4 m.

Acacia melanoxylon

This species was introduced in the late 1860s and is very common in the hills at an elevation of 1,400-2,000 m. It grows very well, becoming a large tree in better soils and when protected from wind. Its main use is as lumber for general construction purposes, fuelwood, and amenity plantings. Initial growth is fast (3 m in the first and second years). Laumans et al. (1983) recorded average growth in arboretum plots of 24-28 m height and 48-57 cm diameter, at age 36 years. Similar growth of 49-53 cm diameter at 45 years was recorded by Sutter (1969).

Acacia dealbata

Introduced at about the same time as *A. decurrens*, *A. dealbata* enjoyed an early popularity for its attractive flowers and habit, rapid growth, and successful early establishment. Its aggressive production of root suckers and its ability to dominate a site encouraged a note of caution to widespread use. This habit and its ability to tolerate weed competition could be exploited in afforestation of marginal lands, but it was largely overshadowed by the success of other bipinnate acacias like *A. decurrens* and *A. mearnsii.*

Acacia mearnsii

A. mearnsii was introduced to Sri Lanka around 1890 as a fast-growing fuelwood species and windbreak. It later gained attention for its potential to produce tan-bark in the up-country, where conditions for its growth above 1,200 m are ideal. Although *A. decurrens* grew faster and yielded acceptable tannin levels, these tannins contained undesirable coloring agents, and so *A. mearnsii* was favored. It grows well on grasslands and enjoys well-drained soils. Growth is rapid with heights of 5-6 m reached in 32 years. Although this species is not currently exploited for tannin production, the past experience described by Macmillan (1946) is of interest. The tan-bark is ready for harvesting 7-8 years after planting and yields of about 17 t/ha can be expected.

Besides the bark, the tree yields useful poles, small timber, and fuelwood. Weeraratne (1964) estimated that 1,000 ha of pure *A. mearnsii* plantations would meet Sri Lanka's projected annual needs for tannin extract of 600 t. Sri Lanka annually imports 390 t of tannin extract and extracts of vegetable origin, with total values of imported tannin extract and tanning chemicals of about Rs. 9 million (about US$320,000) in 1985.

Experience Since 1980

With the emergence of fast-growing Australian acacias, field trials with *Acacia mangium* and *Acacia auriculiformis* were undertaken at different locations with very encouraging results.

A. mangium is now planted on a regular basis in the lowland wet zone and highlands with remarkable success.

To date, no serious problems have been encountered except the observation that they are more prone to fire damage than *Pinus caribaea*, which is planted on sites with similar climatic and edaphic conditions, and which has greater tolerance to fire.

A. auriculiformis has become a popular species for reforestation, especially in the dry zone where its performance has surpassed indigenous species in terms of adaptability, growth, and survival. Its only disadvantage is the poor form which precludes its use for quality poles and sawn timber.

In 1989, the Research Division of the Forest Department embarked on multilocational trials of *Acacia senegal* in the dry zone and the performance was good. It was planted mainly for producing gum arabic.

Results of Growth Trials

The Research Division has been conducting a series of trials to evaluate the relative performance of different acacias, casuarinas and commonly used indigenous and exotic plantation species.

The following trial in the dry intermediate zone illustrates the superiority of *A. auriculiformis* and *A. mangium.* The data are adapted from Weerawardena (1989).

The trial was conducted in the Meegahakiula area, 28 km from Badulla, at an elevation of about 450 m, where annual rainfall is about 1,650 mm. Seeds were sown into seedbeds previously sprayed with an aqueous solution of NPK fertilizer. Most acacia seeds were pretreated with boiling water, but some (*Acacia flavescens, A. oraria and A. rothii)* were nicked instead, and sown directly into polythene tubes.

Other seedlots were sown without any pretreatment. Planting took place in December 1984, using a randomized complete block design, with three replicates. Each plot was a line of 15 trees. A marker plant of *Melaleuca viridiflora* at the end of each plot separated the plots. The perennial grasses that covered the site were uprooted before planting. After planting low slashing and strip weeding were done, as required, to control weeds. Assessments were made at 6, 18, 30, and 42 months after planting. Tables 1-3 present the results.

The tree height at 42 months were analyzed statistically and the results are presented in Table 2.

The greatest dbh was recorded for *A. mangium*. The second was for *A. auriculiformis*. Other species having a large diameter were *A. crassicarpa* and *E. tereticornis* (loc:.'\. The differences for these four species were not significant.

Table 1. Growth and survival (means) from a trial at Meegahakiula.

CSIRO		6 mos.		18 mos.		30 mos.		42 mos.	
Seedlot	Species	ht. (cm)	survival (%)	height (cm)	survival (%)	height (cm)	dbh (cm)	height (cm)	dbh (cm)
13846	*Acacia mangium*	99	91	283	79	655	7.6	1006	11.1
13862	*A. auriculiformis*	130	80	386	78	650	7.9	1034	10.0
13681	*A. crassicarpa*	73	60	312	53	650	7.2	943	8.6
13653	*A. leptocarpa*	89	82	250	75	465	4.5	670	5.0
13871	*A. polystachya*	39	69	135	62	315	2.1	416	3.2
13654	*A. oraria*	34	57	105	47	255	2.7	474	5.3
13588	*Euc. melanophloia*	63	34	184	29	300	2.1	481	3.4
Field	*E. tereticornis*	120	27	356	24	625	4.8	1162	8.4
12944	*E. tereticornis*	80	20	384	20	655	5.1	932	7.3
13349	*E. camaldulensis*	147	27	498	24	715	4.9	973	6.4
Field	*E. torelliana*	102	36	279	33	490	6.3	665	7.0
12848	*E. microtheca*	79	61	164	60	305	1.8	451	5.2
13707	*E. crebra*	65	53	160	44	435	3.2	683	5.2
13400	*E. alba*	15	73	263	56	400	3.5	818	6.8
12966	*E. alba*	17	77	211	77	435	3.2	763	5.7
13515	*Casuarina cunninghamiana*	98	66	260	64	323	2.2	453	4.5
Field	*Calliandra calothyrus*	212	95	385	86	560	5.3	673	6.2
Field	*Leucaena leucocephala*	158	80	542	78	730	6.6	897	8.1
Local	*Tamarindus indica*	41	98	170	88	138	1.5	320	2.7
Local	*Terminalia arjuna*	17	00	000	11				
Local	*Azadirachta indica*	199	100	295	100	418	5.0	518	6.7

Source: Weerawardena (1989)

Table 2. Ranking of mean heights (cm) at 42 months.

Seedlot	Species	Height
Field	*Eucalyptus tereticornis*	1162
13862	*Acacia auriculiformis*	1034
13846	*A. mangium*	1006
13849	*E. camaldulensis*	973
13681	*A. crassicarpa*	943
12949	*E. tereticornis*	932
Field	*Leucaena leucocephala*	897
13400	*E. alba*	818
12966	*E. alba*	763
13707	*E. crebra*	683
Field	*Calliandra calothyrsus*	673
13653	*A. leptocarpa*	670
Field	*E. torelliana*	665
Local	*Azadirachta indica*	518
13588	*E. melanophloia*	481
13654	*A. oraria*	474
13515	*C. cunninghamiana*	453
12848	*E. microtheca*	451
Local	*Terminalia arjuna*	420
13871	*A. polystachya*	416
Local	*Tamarindus indica*	320

Source: Weerawardena (1989)

Table 3. Ranking of mean dbh (cm) at 42 months.

Seedlot	Species	dbh (cm)
13846	*A. mangium*	11.1
13862	*A. auriculiformis*	10.3
13681	*A. crassicarpa*	8.6
Field	*E. tereticornis*	8.4
Field	*L. leucocephala*	8.1
12944	*E. tereticornis*	7.3
Field	*E. torelliana*	7.0
13400	*E. alba*	6.8
Local	*Azadirachta indica*	6.7
13849	*E. camaldulensis*	6.4
Field	*Calliandra calothyrsus*	6.2
12966	*E. alba*	5.7
13654	*A. oraria*	5.3
12848	*E. microtheca*	5.0
13101	*E. crebra*	5.2
13653	*A. leptocarpa*	5.0
13515	*C. cunninghamiana*	4.5
Local	*Terminalia arjuna*	4.3
13588	*E. melanophloia*	3.4
13871	*A. polystachya*	3.2
Local	*Tamarindus indica*	2.7

Source: Weerawardena (1989)

Based on the data in the tables, the following were identified as promising for reforestation:

1. *Acacia mangium* (13846)
2. *A. auriculiformis* (13862)
3. *A. crassicarpa* (13681)
4. *Eucalyptus tereticornis*
5. *E. tereticornis* (12944)
6. *Leucaena leucocephala*
7. *E. camaldulensis* (13849)
8. *E. alba* (12966)
9. *E. torelliana* (local)

A. mangium and *A. auriculiformis* show the best performance in terms of growth increment for the dry intermediate zone areas. *A. crassicarpa*, which is new to Sri Lanka, showed promising results and merits testing of different provenances in future trials.

Future Research

1. Identify good provenances, especially those of *A. auriculiformis* with better form.

2. Broaden the genetic base of *A. mangium* and examine closely the wood properties, especially wood decay.

3. Conduct multilocational trials with hybrids (in particular, *A. auriculiformis* x *A. mangium*).

4. Establish pilot plantation trials of other promising acacias.

5. Establish seed orchards.

6. Establish pilot clonal plantations.

International Linkages

As part of the strategy to address these needs, international linkages will be pursued, including:

1. Strengthening linkages with F/FRED and COGREDA to expand on-going activities.

2. Establishing link with the proposed twinning arrangement to be organized by the FAO/UNDP Forest Tree Improvement Programme (FORTIP)

Acknowledgement

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Discussion Notes

Q: What leads to the classification 'degraded' land in Sri Lanka?

A: Shifting cultivation, mainly in the southeastern part of the island, leaves *Imperata* grasslands and shallow soils. CSIRO seed lots have been planted on these areas in tests.

Q: Are indigenous species planted?

A: Despite their performance on saline soils, indigenous species generally aren't planted—they are considered too slow-growing.

Q: From an interest in matching production to demand, who decides on national priorities and uses in FORTIP? It would be unfortunate to repeat the rubber experience of not considering other possible end uses at the start of an improvement program and thus delay benefits by years when uses are identified later in the process.

A: National meetings were held, involving the full spectrum of government, private sector, and NGO participants.

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Acacias for Rural, Industrial, and Environmental Development in Thailand

Suree Bhumibhamon

Background

The continued destruction of forest resources in Thailand has depleted the growing stock through illegal cutting, slash-and-burn practices, conversion of forest area for farm practices, infrastructure development, and settlement. This over-exploitation has caused a shortage of wood for industrial and household uses. The most serious consequences of deforestation are soil erosion, expansion of saline soil areas, water shortages in the dry season, flash floods in the rainy season, and reduced biodiversity and minor forest products. This has caused society serious economic and environmental constraints. Enrichment planting and tree planting in all forms are greatly needed.

Tree planting has been carried out by government agencies and state enterprises. Farmers have planted fruit trees in homesteads and home gardens. In the last decade, the private sector has started to establish industrial plantations. This development has encountered the problem of scarce land available for tree planting, particularly for those who would like to lease state land for large-scale planting. Non-government organizations (NGOs) in general have confronted attempts to make state lands available in this way, but are weak in suggesting alternatives by which sufficient wood can be supplied to meet the needs of Thailand's households and wood industry. Self-reliance on tree products can be promoted through small-scale tree farming, farm woodlots, and agro-forestry. Multipurpose tree species can be suitable for marginal areas and provide farmers with multipurpose products. In Thailand, farmers grow bamboo, mango, jackfruit, coconut, and other fruit trees whose wood can be used for fuelwood and household uses. *Acacia catechu* and *A. insuavis* are also commonly grown on private land, mainly for personal use.

Acacias in Rural Development in Thailand

Rural communities rely heavily on wood and minor forest products gathered from natural forests. The scarcity of these products is mainly caused by population and road density, poverty, agricultural crop yields, distance to the market, and wood prices. Conversion of forest to farmland has increased considerably during the last three decades and has been an important factor in the depletion of forest products. The Thailand Forestry Sector Master Plan has projected the forest cover for the year 2000 and predicts more loss of forest resources in most parts of the country. To prevent this, a land-use policy must be established, the cultivation of cash crops must be abolished, land tenure must be given and agricultural credit expanded, birth control must be promoted more vigorously, and more trees need to be planted.

Bhumibhamon (1992) identified 13 *Acacia* species native to Thailand. Among them, *A. catechu* is grown mainly in the central and northeastern parts of the country. It is planted as a shelterbelt, often mixed with bamboo. *A. insuavis* (or *seesiat nuea* in Thai) is grown in homesteads as a source of food. Table 1 shows 13 key native and exotic *Acacia* species.

Table 1. Key native and exotic *Acacia* species in Thailand.

Native	Exotic
Acacia catechu	*A. farnesiana*
A. concina	*A. auriculiformis*
A. insuavis or *A. pennata*	*A. crassicarpa*
A. leucophloea	*A. mangium*
A. pennata	*A. aulacocarpa*
A. tomentosa	*A. holosericea*
	A. difficilis

Of exotic acacias, *A. farnesiana* (or *kam tai*) was reportedly introduced from Cambodia or India during the fourteenth century A.D. The shoot and pod can be used as a vegetable.

A. auriculiformis was introduced to Thailand from Australia by Tan Khun Narong a few decades ago. It is found to grow well in many villages as a decorative tree and fuelwood source.

A. mangium has recently been introduced into homesteads and private farms as a potential tree to grow for wood. *A. crassicarpa* is still in research station trials, and may be introduced to private farms in the near future.

As a source of food, young shoots of *A. insuavis* are used in cooking, either eaten raw or soaked in hot water. Often the young shoot is cooked in the form of an omelette and eaten with chili paste. The young leaf of *A. concinna* (or *som poi*) is used to flavor food.

As a source of medicine, the concoction of young leaves of *A. concinna* boiled and mixed with honey is used as a diuretic (Pongpangan and Poobrasert 1991). Pods of this species are sold locally as shampoo. They are also used as a mild cathartic and emetic (McFarland 1944).

Seeds of *A. catechu* are used to control skin disease. The tree bark has catechol, gallic acid, and tannin. Boiled, it serves as local medicine to control diarrhea, and dysentery (Thiengburanatam 1989). The heartwood is called *cutch*. Pure cutch is used for chewing. When powdered and dissolved in hot water, it can be used as a medicine to control diarrhea. In some countries, the tree's tannin is used for dyeing dark leather, cotton and silk.

The Thai rural community uses acacia woods for farm tools, fuelwood, charcoal, and tannin extraction. *A. catechu* wood is red or reddish, very durable, and suitable for making hand tools and cart-wheels.

A. pennata (or *nam han*) is another useful medicinal plant which grows in open areas throughout the country. The leaves are made into a poultice and applied to the head for curing headaches. The boiled root is applied as a poultice for rheumatism or rubbed over the body for smallpox. Sometime, the root is used to treat coughs. The tannin can be used for staining fishing nets (McFarland 1944).

A. leucopholoea (or *cha laeb daeng*) is now rarely found in Thai villages. It is a medium-sized or large tree which can be used for house and bridge construction, and for furniture.

Formerly, the heartwood was also used for tannin extraction.

A. catechu and *A. auriculiformis* are commonly used in rural areas for fuelwood. The calorific values of fuelwood of *A. auriculiformis* is 4,600 calories per gram; for *A. catechu*, the value is 7,523 calories per gram, and for *A. siamensis*, 4,792 calories per gram. When processed to charcoal, calorific value increases considerably.

Acacias in Industrial Development

A. farnesiana has fragrant flowers and is used in France in the perfume industry. This use is little known in Thailand. *A. catechu* has no current industrial use except for charcoal production (however, see the paper by Wanida Subsansenee et al. in this proceedings).

Tannin from *A. auriculiformis* bark is used in tanning leather. Due to poor tree form, its wood can be used only for the parquet industry, and it is not commonly used as industrial wood for pulp and paper due to the limited supply. The Thai Plywood Co. uses this species as raw material for fiberboard. The product is good but the bark's high chemical content requires more chemical treatment of the waste water than other species.

Trials of 28 provenances of *A. auriculiformis*, established with support from F/FRED, found that although tree form is relatively poor, it can be improved through individual tree selection. The species flowers profusely, which raises the possibility of apiculture for honey production.

Wood of *A. mangium* has been tested in private sawmills in Buriram and is an excellent source of sawn timber. Bhumibhamon et al. (1992) found a high degree of family variation in heartwood formation. Progeny testing and seed improvement are being conducted under a cooperative tree improvement program between Kasetsart University and the Thai Plywood Co. Due to the species' good productivity under plantation conditions, the species has gained favor among tree farmers in central Thailand. Like *A. auriculiformis*, *A. mangium* flowers well and is suitable for honey production.

Preliminary results indicate that *A. crassicarpa* is an excellent choice for industrial use in Thailand. Species and provenance trials are underway at various sites in the country.

Acacias in Environmental Development

A number of acacias grow well on degraded land, and can be suitable to grow as alternatives to shifting cultivation. *A. catechu* grows well in drought-prone areas and resists forest fire. It is an excellent pioneer species and can coppice well. *A. auriculiformis* grows well in most sites in Thailand, and could be used to establish green areas. It also grows well in poor sites, particularly on former tin-mining sites in the South.

A. mangium is suitable for growing in *Imperata* -infested grassland. If planted at a spacing of 3 x 3 m, the canopy of *A. mangium* will close in two years and suppress the *Imperata* grass. In urban areas, *A. mangium* is now popular for growing in golf courses, gasoline stations, and along roadsides.

Trends in Research and Development

A summary of prospects for acacia prospects in rural, industrial, and environmental development is suggested in Table 2. Potential research on acacias in Thailand include:

1. Species *cum* provenance trials in problem soils in various parts of the country, in view of the fact that land available for tree planting is mostly on marginal sites

2. Studies of growing acacias as an alternative to unsustainable shifting cultivation, including degraded sites

3. Hybridization studies

4. Physiological studies for selection of clones and families

5. Tests of growth and production under agroforestry, to introduce the trees to farm areas

Discussion Notes

Thailand's list of reserve species includes 240 species. Seventy-two native species are currently planted, including *A. catechu* (1 million trees in the past 90 years); 27 exotic species are planted, including *A. auriculiformis* (only in test plantings so far) and *A. mangium* (grown by farmers for sale to industry).

With the current logging ban, saw mills in Thailand are closing and tree growing is hard to encourage. Cutting rights linked to planting must be offered.

Research needs

Exploration	*A. catechu, A. tomentosa*
Seed collection	*A. catechu* (by RFD, ACFTSC) *A. mangium* (RFD, ACFTSC, Thai Plywood Co.) *A. auriculiformis* (RFD, ACFTSC)
Planting	*A. catechu* (as living fence, on degraded land) *A. auriculiformis* (on degraded land) *A. mangium* (by farmers for industrial processing)

Comment: Nutrient cycling is a research area that should also be considered; in second rotation *Alnus* plantings, for example, nutrient deficiences were discovered. Sure, most acacias fix nitrogen, but nitrogen is not the only nutrient needed for trees or other crops.

Q: What incentives are there for the private sector to become involved in plantations?

A: Soft loans, which haven't worked in Thailand due to the high interest rate (12%, vs. 3% in other countries), and land leasing, which was banned in recent years due to instances in which community forest lands were leased for plantation without consultation. The Plantation Act of 1991 did not provide adequate incentive, because it mainly dealt with the reserve species, mostly indigenous, which are less known in terms of properties and markets.

Table 2. Prospects for acacias in Thailand.

Species	Rural Development				Industry			Environment		
	Fuel	Tannin	Medicine	Food	Sawnwood	Fiberboard	Other	Enrichment planting	Degraded land	Urban forestry
Acacia aulacocarpa						?				
A. auriculiformis	x				x	x	parquet		x	x
A. catechu	x	x	x				cutch	x	x	
A. concina										
A. crassicarpa					?					
A. farnesiana							perfume			
A. insuavis				x						
A. leucophloea										
A. mangium	x				x	x	pulp, paper, veneer		x	x
A. pennata			x							
A. tomentosa	x		x					x		

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Acacias for Rural, Industrial, and Environmental Development in Vietnam

Nguyen Hoang Nghia and Le Dinh Kha

Introduction

Vietnam has a total area of about 330,000 km^2 of which 19 million ha is forest and forest land (about 60% of the country's area). At the end of 1989, natural forest was estimated at 8,686,700 ha, forest plantation at 629,000 ha, and land without forest at 9,315,700 ha (Ministry of Forestry 1991). The area under forest can be classified into three utilization categories: productive forests, protected forests, and special forest.

Vietnam's government has established an action plan for greening 5 million ha of bare hills and denuded land in the next 10 years to supply wood for the pulp and paper industry, sawn wood, mine poles, fuelwood, and other forest products. *Acacia* species occupy an especially important place in this reforestation program, particularly for supplying raw material for pulp and paper for export, and for environmental protection.

Native and Introduced Acacias

According to the plant classification work of Lecomte (1908), Vietnam has two native *Acacia* species: *Acacia donnaiensis* Gagnep and *A. intsia* Willd. *A. intsia* is widely planted on farms in the northern part of the country, and its leaves are used in cooking soups. In general, though, these acacias are small trees, shrubs, or climbing plants, and have not been included in any reforestation program.

In the 1960s in southern Vietnam, many exotic acacias were introduced for trial and planting (Table 1). Of these, *A. podalyriifolia* (also *A. podalriaefolia*, or "mimosa") and *A. auriculiformis* are the two most widely known. *A. podalyriifolia* has brilliant silver leaves and yellow flowers, and is prized as an ornamental tree, especially in Dalat city, LamDong province. *A. auriculiformis* was one of the early planting species introduced into Vietnam, and is particularly common in southern Vietnam. At the Forest Research Centre of southeastern Vietnam (Trang Bom, Thong Nhat, DongNai province), some older trees (about 30 years old) of *A. auriculiformis* have an average height of about 20 m and diameter of 40-60 cm. The largest trees have diameters of 80 cm.

At about the same time, *A. confusa* was also introduced from China into the northern provinces of Vietnam.

Table 1. Acacias introduced in 1960s in southern Vietnam, according to documents maintained.

No	Species	Year of introduction
1	*Acacia aneura*	1964
2	*A. angolacocarpa*	1964
3	*A. aulacocarpa*	1964
4	*A. auriculiformis*	1964
5	*A. bracatinga*	unknown
6	*A. corymbosa*	1964
7	*A. decurrens*	1964
8	*A. excelsa*	1964
9	*A. harpophylla*	1964
10	*A. longifolia*	1964
11	*A. melanoxylon*	1967
12	*A. nodosa*	1964
13	*A. pendula*	1964
14	*A. podalyriaefolia*	1960, 1961
15	*A. retinoides*	unknown

After 1975, *A. auriculiformis* became a popular tree species in northern provinces as well, and so has been planted widely throughout the country. According to the Ministry of Forestry (1991), the area of *A. auriculiformis* plantation and local supplies of seed used in recent years are as follows:

	Area (ha)	Seed qty (kg)
1986	1015	not available
1987	2324	800
1988	836	786
1989	620	500
1990	800	600

Since 1980, with assistance from projects and international organizations, seeds of many promising tropical acacias have been put in trials and planted on a large scale, including *A. auriculiformis*, *A. mangium* *A. crassicarpa*, *A. aulacocarpa*, *A. cincinnata*, *A. melanoxylon*, and *A. mearnsii*. Of these more recent introductions, *A. mangium* has become the preferred *Acacia* species. Vietnam's imports of seed of this species went from 80 kg in 1989 to 800 kg in 1990 (Ministry of Forestry 1991). In the action plan for planting 1.5-1.6 million ha of productive forests (out of a total 5 million ha to be reforested) by the year 2000, 10% of this area is intended for planting *Acacia* species (i.e., about 130,000-150,000 ha).

Acacia-Planting Programs in Vietnam

The Government's new policy on forest and forest land allocation provides a good basis for farmers who are interested and invested in reforestation. In the plains, *A. auriculiformis* and *A. mangium* have been planted widely along roads as ornamental trees that also yield wood and fuelwood for farmers. In mountainous areas, people have been also encouraged to plant acacias with eucalypts for forest rehabilitation and soil and environmental protection.

Beside productive forests, there is a large area of protected forests and river-head forests to be maintained, preserved and covered with trees. Among the many tree species used for this purpose, are some acacias, principally *A. auriculiformis* and *A. mangium*. The World Food Program (WFP) Reforestation Project No. 4304 aims to plant 125,000 ha with plantations in 1993-1997 in 13 coastal provinces. It provides seeds, seedlings, and funds directly to families. *Acacia* species occupy a high priority in that program.

There is a new trend in Vietnam to use wood of *Acacia* species for pulp and paper production. The area planned for planting acacias for this purpose is increasing to about 10,000-15,000 ha annually, but it is a long-term task. In some wood-processing factories, acacia wood has been used for furniture. Wood of *A. auriculiformis* has been exported. Although the export price is only half that for eucalypts, acacia's superior characteristics in soil and environment protection has prompted the Government to favor acacia planting over eucalyptus.

Planting trees on denuded land can give good prospects for rural and economic development. It is hoped that the case of *A. mangium* on acid sulphate soil can be a good example of this.

A. mangium on acid sulphate soil

About one million ha of acid sulphate soil in southern Vietnam is not productively used. Although the soil is quite fertile (Table 2), the low pH (3.2-3.5 KC1), waterlogging in the rainy season, and high sulphate potential make it very difficult to cultivate agricultural crops there.

For planting trees in these soils, a new technique should be applied by which soil is dug to make banks or raised beds (0.5 m high and 2-4m wide) and a canal system to adjust the water level between them.

Acacias and eucalypts have been planted on banks and along roads in these areas. Table 3 shows growth data of *A. mangium* planted in trial at Tan Tao Station (Ho Chi Minh City). In these areas, low-density plantings show better growth than high-density plantings. Also, on newly established banks with more fertile soil, *A. mangium* growth is quite good (height measurements taken for main stem only) but tends toward a multi-stemmed habit: 93% of the trees have more than one stem, with an average of more than 3 stems per tree.

A. auriculiformis and *A. mangium* have proven to be promising for this ecological region. With these two species planted widely on this acid sulphate soil, the great potential of these areas could be exploited for better population distribution, employment, rural development, and production of raw materials for the pulp and paper industries.

Species and Provenance Trials

In the early 1980s, provenances of *A. mangium*, *A. auriculiformis*, *A. crassicarpa*, and *A. aulacocarpa* were put in trial in areas such as Da Chong (Ha Tay province, 1982), Hoa Thuong (Bac Thai, 1984), and Dai Lai (Vinh Phu, 1985) (Le Dinh Kha and Nguyen Hoang Nghia 1991; Nguyen Hoang Nghia 1992). Some research and production organizations have also conducted trials and plantings in their locality. The trials conducted by the Forest Science Institute of Vietnam have shown particularly promising growth potential of *A. mangium*, followed by *A. auriculiformis* and *A. crassicarpa*. Only *A. aulacocarpa* showed both slow growth and multi-stem habit (average 3-

Table 2. Features of soil samples taken from banks in Tan Tao Station (Ho Chi Minh City).

Soil layer (cm)	Humus (%)	N (%)	P_2O_5 (%)	K_2O (mg/100 g)	pH (KCl)
0 - 10	10.2	0.27	1.6	21.6	3.2
15 - 25	12.5	0.31	1.5	41.3	3.3
30- 60	7.2	0.24	1.7	20.9	3.5

Table 3. Mean annual increment of *A. mangium* (Seedlot 0407, Dendros, Australia) planted at Tan Tao Station.

Age (years)	Spacing (m)	Ht (m) /year	Dia (cm) /year	Stems per tree	% Single-stemmed trees
4.3*	4 x 6	2.6	3.4	1.6	50
4.3**	1.5 x 1.5	2.1	2.1	1.3	70
3.3*	4 x 6	3.1	3.9	1.2	80
2.3*	4 x 6	4.4	5.2	1.5	67
1.5***	1.5 x 3.0	3.6	4.1	3.1	7

*planted along road; **planted on old bank; ***planted on new bank

4 stems/tree, with 79-97% of trees having more than one stem).

Provenance trials of *A. mangium*

In the late 1980s, some provenance trials were established for the most promising Acacia species namely A. mangium. Data collected from 4 trials carried out in 3 sites, Dai Lai (Vinh Phu province, 1988), Bau Bang (Song Be, 1988), and LaNgea (Dong Nai, 1989 and 1990), are shown in Table 4.

Other *A. mangium* provenances are also in trial at Bau Bang and La Nga, but for comparative purposes, Table 4 includes only those which were also in the trial at Dai Lai.

It clear that on the dry, bare hills in the midlands of northern Vietnam, of which the Dai Lai trial site was considered representative, height growth of *A. mangium* (about 1.2 m/year) was much lower than at sites in southern Vietnam (Bau Bang, La Nga; 2.2-2.5 m/year). Promising provenances from these trials are Cardwell (especially in southern Vietnam), Kennedy, Hawkins Creek, and Kuranda (all from Queensland, Australia).

Species and provenance trials

Thirty-nine provenances of 5 *Acacia* species were put in trials at Da Chong (Ha Tay province, 1990), Dai Lai (Vinh Phu, 1991), Dong Ha (Quang Tri, 1991), and La Nga (Dong Nai, 1991), with details as follows:

A. aulacocarpa (5 provenances)
A. auriculiformis (13 provenances)
A. cincinnata (3 provenances)
A. crassicarpa (9 provenances)
A. mangium (9 provenances)

Tables 5 and 6 show growth data at 27 months. Compiled by species, mean growth data is:

	Ht (m)	Dia (cm)
A. crassicarpa	4.8	6.7
A. auriculiformis	4.8	6.8
A. mangium	4.3	6.9
A. aulacocarpa	3.2	4.8
A. cincinnata	3.1	5.1

The most promising provenances appear to be Pongaki E.M. of *A. mangium*; Coen River and Kings Plains of *A. auriculiformis*; and Pongaki E.M., Gubam and Mata Prov. of *A. crassicarpa*.

Table 4. Ranking of *A. mangium* provenances in some trials by height growth (m).

Dailai, 36 months		Bau Bang, 36 months		La Nga, 20 months		La Nga, 9 months	
Seedlot	Ht (m)	Seedlot	Ht (m)	Seedlot	Ht (m)	Seedlot	Ht (m)
31 I	3.8	34 I	7.0	26	6.1	26	1.2
27 II	3.3	26	6.2	31 I	5.9	0515	1.1
34 I	3.3	31 I	6.1	34 I	5.7	27 II	1.1
0407	3.2	27 I	5.4	0515	5.7	15367	0.9
0515	2.8			33 I	5.6	15700	0.8
27 I	2.8			0407	5.1	0517	0.8
33 I	2.6						
26	2.4						
30 II	1.6						

Seedlot	Provenance
26; 15700	Cardwell
27I; 27II	Kuranda
30II; 0517	Ingham
0515; 15367	Mossman
31 I	Hawkins
33 I	Bronte
34 I	Kennedy
0407	Dendros Seed Suppliers

Conclusion

Three *Acacia* species—*A. mangium*, *A. auriculiformis*, and *A. crassicarpa*—show promising results. Beside quite rapid growth, acacias also show good ability to protect soil and fix nitrogen for increased soil fertility and environmental protection. In the coming years, the promising provenances will be determined for large-scale planting and establishement of local seed stands. Research on breeding *A. mangium* and *A. auriculiformis* has already begun.

In addition to research, new efforts should be made to disseminate information widely on these trees' uses and processing technologies, so that there is a good information and market basis for developing their production and use in the country.

Table 5. Height and survival of 27-month-old *Acacia* provenances, Da Chong (Multiple Range Test).

Seed -lot	Species	Provenance	Mean Ht (m)		Survival (%)
16589	*A. mangium*	Pongaki E.M.	5.6	I	82.9
16599	*A. crassicarpa*	Pongaki E.M.	5.6	I	74.1
16142	*A. auriculiformis*	Coen R.	5.5	I I	78.1
16597	*A. crassicarpa*	Gubam Village	5.4	I I	76.9
13681	*A. crassicarpa*	Mata Prov.	5.1	I I I	72.6
16485	*A. auriculiformis*	Kings Plains	5.0	I I I	89.1
16484	*A. auriculiformis*	Morehead R.	5.0	I I I I	87.1
16106	*A. auriculiformis*	Mibini	5.0	I I I I	85.7
16605	*A. crassicarpa*	Derideri	5.0	I I I I	75.5
16148	*A. auriculiformis*	Manton R.	4.8	I I I I	90.9
16152	*A. auriculiformis*	E.Alligator R.	4.8	I I I I	97.9
16602	*A. crassicarpa*	Dimisisi V.	4.8	I I I I	54.8
15677	*A. mangium*	Iron Range	4.8	I I I I	78.5
13680	*A. crassicarpa*	Wemenever	4.7	I I I I	72.9
16107	*A. auriculiformis*	Old Tonda V.	4.7	I I I I	96.1
16163	*A. auriculiformis*	Elizabeth R.	4.7	I I I I	89.7
16598	*A. crassicarpa*	Bimadebun	4.6	I I I I	63.3
16154	*A. auriculiformis*	Goomadeer R.	4.6	I I I I	89.8
16113	*A. aulacocarpa*	Keru to Mata	4.5	I I I	86.4
15678	*A. mangium*	Helenvale	4.5	I I I	83.6
16683	*A. auriculiformis*	Morehead R.M	4.5	I I I I	90.0
16151	*A. auriculiformis*	Mary R.	4.5	I I I I	89.2
13682	*A. crassicarpa*	Oriomo	4.4	I I I	83.6
16586	*A. mangium*	Gubam	4.4	I I I	70.5
16158	*A. auriculiformis*	Gerowie Creek	4.4	I I I	87.7
16681	*A. mangium*	Ingham	4.3	I I I I	81.5
16684	*A. auriculiformis*	Bensbach	4.2	I I I I	80.2
16679	*A. mangium*	Bloomfield-Ayton	4.0	I I I	89.3
15367	*A. mangium*	Mossman	4.0	I I I	77.6
16112	*A. aulacocarpa*	Morehead	3.9	I I	81.5
13621	*A. mangium*	Piru, Ceram	3.7	I I	75.0
15694	*A. mangium*	Townsville	3.4	I I	78.9
15691	*A. cincinnata*	Julatten	3.4	I I I	82.7
16128	*A. crassicarpa*	Jardine R.	3.3	I I I	87.2
13864	*A. cincinnata*	Shoteel L.A.	3.3	I I I	81.2
15365	*A. cincinnata*	Mossman	2.6	I I	77.8
13866	*A. aulacocarpa*	Garioch	2.6	I I	42.8
13865	*A. aulacocarpa*	Buckley L.A.	2.6	I I	67.1
16180	*A. aulacocarpa*	Maningride	2.4	I	61.9

Table 6: Diameter growth of 27-month-old *Acacia* provenances, Da Chong (Multiple Range Test).

<table>
<tr><th>Seedlot</th><th>Species</th><th>Provenance</th><th>Mean Dia (cm)</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>16589</td><td>A. mangium</td><td>Pongaki E.M.</td><td>8.3</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>13681</td><td>A. crassicarpa</td><td>Mata Prov.</td><td>7.8</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16142</td><td>A. auriculiformis</td><td>Coen R.</td><td>7.7</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16597</td><td>A. crassicarpa</td><td>Gubam Village</td><td>7.6</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16681</td><td>A. mangium</td><td>Ingham</td><td>7.4</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15677</td><td>A. mangium</td><td>Iron Range</td><td>7.2</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16485</td><td>A. auriculiformis</td><td>Kings Plains</td><td>7.2</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>15678</td><td>A. mangium</td><td>Helenvale</td><td>7.1</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16605</td><td>A. crassicarpa</td><td>Derideri</td><td>7.1</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16154</td><td>A. auriculiformis</td><td>Goomadeer R.</td><td>7.1</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16152</td><td>A. auriculiformis</td><td>E.Alligator R.</td><td>7.1</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16106</td><td>A. auriculiformis</td><td>Mibini</td><td>7.0</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>16586</td><td>A. mangium</td><td>Gubam</td><td>7.0</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16148</td><td>A. auriculiformis</td><td>Manton R.</td><td>7.0</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16599</td><td>A. crassicarpa</td><td>Pongaki E.M</td><td>6.9</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>15367</td><td>A. mangium</td><td>Mossman</td><td>6.9</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16602</td><td>A. crassicarpa</td><td>Dimisisi V.</td><td>6.8</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16163</td><td>A. auriculiformis</td><td>Elizabeth R.</td><td>6.8</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16484</td><td>A. auriculiformis</td><td>Morehead R.(Q)</td><td>6.8</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16158</td><td>A. auriculiformis</td><td>Gerowie Creek</td><td>6.7</td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>15694</td><td>A. mangium</td><td>Townsville</td><td>6.7</td><td></td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16683</td><td>A. auriculiformis</td><td>Morehead R.</td><td>6.6</td><td></td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16679</td><td>A. mangium</td><td>Bloomfield-Ayton</td><td>6.6</td><td></td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td><td></td></tr>
<tr><td>16598</td><td>A. crassicarpa</td><td>Bimadebun</td><td>6.6</td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>16151</td><td>A. auriculiformis</td><td>Mary R.</td><td>6.4</td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>16107</td><td>A. auriculiformis</td><td>Old Tonda V.</td><td>6.3</td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>13682</td><td>A. crassicarpa</td><td>Oriomo</td><td>6.3</td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>13680</td><td>A. crassicarpa</td><td>Wemenever</td><td>6.3</td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>16684</td><td>A. auriculiformis</td><td>Bensbach</td><td>6.0</td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td></tr>
<tr><td>16112</td><td>A. aulacocarpa</td><td>Morehead</td><td>5.7</td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td><td></td></tr>
<tr><td>15961</td><td>A. cincinnata</td><td>Julatten</td><td>5.6</td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td><td></td><td></td></tr>
<tr><td>16113</td><td>A. aulacocarpa</td><td>Keru to Mata</td><td>5.5</td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td><td></td></tr>
<tr><td>13864</td><td>A. cincinnata</td><td>Shoteel L.A.</td><td>5.2</td><td></td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>13865</td><td>A. aulacocarpa</td><td>Buckley L.A.</td><td>5.1</td><td></td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>16128</td><td>A. crassicarpa</td><td>Jardine R.</td><td>5.0</td><td></td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>13621</td><td>A. mangium</td><td>Piru, Ceram</td><td>4.8</td><td></td><td></td><td></td><td></td><td></td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>15365</td><td>A. cincinnata</td><td>Mossman</td><td>4.4</td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td><td>|</td></tr>
<tr><td>13866</td><td>A. aulacocarpa</td><td>Gerioch</td><td>3.8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td></tr>
<tr><td>16180</td><td>A. aulacocarpa</td><td>Maningrida</td><td>3.8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td></tr>
</table>

Discussion Notes

Q: What is the cause of the acidic soil conditions in southern Vietnam?

A: They occur naturally due to the Mekong delta. When this land that was originally under sea level became exposed, sulphate results. The problem in reforesting these acid soils is the high investment cost, particularly for small farmers.

Comment: This is the same obstacle as in Taiwan, where the investment required made it unfeasible for individual farmers.

Q: Regarding your mention of the higher price for eucalypts, why should farmers invest in acacias?

A: That is a policy decision by the Government.

Comment: *A. mangium* has a doubtful future on waterlogged soils.

Comment: Still, some acacias do tolerate waterlogging. For example, *A. auriculiformis* has survived 2-3 months of waterlogging. Planting on mounds helps the trees to establish. Eucalypts survive waterlogging because their roots spread laterally, not down. This probably happens with acacias also. At a trial near Nakhon Ratchasima, both *E. camaldulensis* and *A. mangium* survived 3 months of waterlogging.

Comment: However, in the situation presented in Vietnam, the trees would have to tolerate sulphate as well as waterlogging, a difficult demand.

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Genetic Resources of Fifteen Tropical Acacias

Khongsak Pinyopusarerk

Introduction

The genus *Acacia* comprises more than 1,000 species widely distributed in Africa, the Americas, Asia, and Australia. Acacias occupy a wide variety of habitat types, ranging from arid zones to rainforest fringes, and occur in both tropical and temperate zones. Individual species vary from prostrate shrubs less than 1 m tall to large forest trees attaining 35 m in height and 1 m in diameter.

Many acacias from the humid/subhumid tropics (e.g., *A. mangium, A. auriculiformis, A. crassicarpa,* and *A. aulacocarpa*) are suitable reforestation species for wood production for pulp, sawn timber, and fuelwood (Awang and Taylor 1992). Other acacias from dry tropical environments (e.g., *A. ampliceps* and *A. holosericea*) are useful for rehabilitation programs. Some lesser-known species, including *A. leptocarpa* and *A. cincinnata,* have shown potential for use in agroforestry.

The first meeting of the Consultative Group for Research and Development of Acacias (COGREDA), held in Phuket, Thailand in June 1992, reviewed past work and experience with acacias in the humid and subhumid tropics of East Asia and the Pacific (Awang and Taylor 1992). The meeting also identified a range of *Acacia* species with potential value for rural, industrial, and environmental development. This paper reviews the genetic resources of the 15 species in Table 1 that have main geographic occurrence in Australia. These species have known or potential value for rural, industrial and environmental development. Table 1 includes information on their geographic occurrence and ecological range. Figures 1-13 show the generalized distribution of these species. General information dealing with natural distribution has been discussed in Turnbull (1986) and Thomson (1992a) and is reproduced here.

Some acacias with wide geographic distributions extending over a range of environmental conditions are likely to have high levels of genetic diversity. Genetic variation studies of species now being used or with a high potential for use in plantations are needed to provide a basis for selecting the most suitable seed sources for planting and for developing appropriate strategies and base populations for tree breeding and conservation. Some progress has already been made in exploring intraspecific variation in the genus *Acacia*, especially in some of the species listed in Table 1.

Seed Availability

Current availability of provenance seed collections of these species held at the Australian Tree Seed Centre (ATSC) is given in Table 1. ATSC is the principal supplier of research seed for these *Acacia* species. Single-tree collections have also been made, allowing the study of variation at the within- and between-provenance levels. The Centre's staff usually collect the seed from natural stands themselves, but sometimes private seed collectors are

Table 1. Characteristics of some tropical *Acacia* species with potential for rural, industrial and environmental development.

Species	Country/ State	Latitudinal range (^{o}S)	Altitudinal range (m)	Rainfall range (mm)	Soil Texture	Soil pH	Tree form and height	Primary Utilization	Availability of seed from natural range (ATSC)
A. ampliceps	NT, WA	14-26	0-400	200-800	sandy/ clay	alkaline	spreading large shrub/small tree, 3-9 m.	fuelwood, reclamation of salt-affected sites	good
A. aulacocarpa	IND, PNG, NT, QLD, WA, NSW	6-30	0-1000	500-3000	sandy-clay	acid-alkaline	small shrub or tree to 10 m in dry sites but large tree up to 35 m on moist sites	cabinet timber, general constuction, pulp	good
A. auriculiformis	PNG, IND, NT, QLD	5-17	0-400	750-3000	sandy-clay	acid-alkaline	more commonly short crooked stem tree 8-20 m but superior provenance grows to 25-30 m with a straight stem on favourable sites	fuelwood, pulp, aesthetic, erosion control, small sawn wood eg. window frames	good
A. brassii	QLD	11-14	0-200	500-1800	sandy	acid	small tree/shrub, 4-10 m.	fuelwood, low shelter	fair
A. cincinnata	QLD	16-28	150-750	750-3500	sandy-clay	acid-alkaline	tree to 35 m, but smaller <10 m on drier sites	fuelwood, cabinet timber	fair
A. colei	QLD, NT, WA	14-23	0-750	250-1000	sandy-clay	acid-alkaline	large shrub/small tree, 3-9 m	fuelwood, human food potential	good
A. crassicarpa	PNG, IND, QLD	8-20	0-700	500-3500	sandy-clay	acid-alkaline	large tree to 30 m but small shrub/tree 5-20 m on less favourable sites	fuelwood, general construction	good
A. difficilis	QLD, NT, WA	11-18	0-200	450-1500	sandy-clay	acid-neutral	large shrub/small tree, 10 m.	fuelwood, low shelter, erosion control on sandy soils	poor
A. holosericea	QLD, NT, WA	11-24	0-750	250-1600	sandy-loam	acid-alkaline	large shrub/small tree, 4-9 m.	fuelwood, rehabilitation mining area, sand dune fixation, human food potential	good
A. leptocarpa	QLD, NT, WA, PNG, IND	8-26	0-550	350-1750	sandy-clay	acid	small shrub/tree, 3-12 m.	fuelwood, agroforestry	poor

NSW = New South Wales; NT = Northern Territory; QLD = Queensland; WA = Western Australia; IND = Indonesia; PNG = Papua New Guinea

Table 1 continued.

Species	Country/ State	Latitudinal range (^{o}S)	Altitudinal range (m)	Rainfall range (mm)	Soil Texture	Soil pH	Tree form and height	Primary Utilization	Availability of seed from natural range (ATSC)
A. mangium	PNG, IND, QLD	1-18	0-800	1000-3000	sandy-loam	acid-alkaline	large tree to 30 m.	fuelwood, general construction, pulp, revegetation of grassland	good
A. neurocarpa	WA, NT	14-19	0-750	350-1250	sandy-loam	neutral	spreading shrubby tree, 3-6 m	fuelwood, human food potential	poor
A. oraria	IND, QLD	8-22	0-700	900-2150	sandy-clay	acid-alkaline	spreading shrub/tree to 15 m.	fuelwood, reclamation of grasslands	poor
A. plectocarpa	WA, NT	11-28	0-300	300-1600	sandy	acid	shrub/small tree, 3-10 m.	fuelwood	poor
A.. polystachya	QLD	10-19	0-500	500-2150	sandy-clay	acid-alkaline	small shrub 3-4 m, into tree 25 m.	fuelwood	poor

NSW = New South Wales; NT = Northern Territory; QLD = Queensland; WA = Western Australia; IND = Indonesia; PNG = Papua New Guinea commissioned. Priority is generally given to species for which the demand for seed is high. Comprehensive collections have been made for *A. mangium*, *A. auriculiformis*, *A. aulacocarpa*, and *A. crassicarpa*. Other species (including *A. brassii*, *A. plectocarpa*, and *A. polystachya*) are not well represented.

Seed of some Australian acacias that have been long established as exotics (particularly *A. mangium* and *A. auriculiformis*) is also available from *ex situ* sources. *A. auriculiformis* seed has been supplied from India and Thailand. Sabah Softwoods Sdn. Bhd. in Malaysia has been a major supplier of *A. mangium* seed since the 1980s. Improved quality seed of *A. auriculiformis* can now be obtained from seed orchards established in northern Australia by ATSC. Seed orchard seed of *A. mangium*, *A. aulacocarpa*, and *A. crassicarpa* is expected to be available in the near future.

Natural Distribution

A. ampliceps

A. ampliceps is a spreading large shrub or small tree up to 9 m tall, useful for rehabilitating sand dune and salt-affected sites. It has survived and grown well in salt-affected areas in Thailand and Pakistan (Marcar et al. 1991), and has performed well on alkaline soils in Timor, Indonesia (McKinnell and Harisetiono 1991). At the Nacula fuelwood trial in Fiji, measurement at 3.5 years after planting showed that *A. ampliceps* had the fastest height growth and highest survival rate, out-performing *A. crassicarpa*, *Paraserianthes falcataria*, and *Eucalyptus. camaldulensis* (Kubuabola et al. 1992).

The natural occurrence of *A. ampliceps* is between latitude 14 and 26°S in northwestern Western Australia and the Northern Territory (Plate 1). It is also scattered throughout arid and semi-arid inland areas in the southern Kimberleys and northern part of the Northern Territory (Turnbull 1986). Altitudinal range is from sea level to about 400 m. The performance of this species as reported in Fiji, Indonesia, Pakistan, and Thailand warrants further investigation of the genetic resources. Current seed availability at ATSC is considered adequate for such studies.

A. aulacocarpa

A. aulacocarpa is one of the largest acacias, reaching 35 m with a diameter in excess of 1 m on moist sites associated with tropical rainforest. On drier sites it occurs as a shrub or small tree 4-10 m. There are also differences in the shape and color of phyllodes between populations distributed in the moist and dry areas. This morphological variation is the focus for current taxonomic attention.

A. aulacocarpa has a very wide distribution, with a latitudinal range of 6-30°S and an altitudinal range from near sea level to 1,000 m (Turnbull 1986). It is found from southern Papua New Guinea (PNG) to northern New South Wales. The northern occurrence is in the Western Province of PNG and the adjoining area of southeastern Irian Jaya. In Australia it has two disjunct occurrences: the main population extends along the east coast from Cape York Peninsula to northern New South Wales; the second area is in the northern part of the Northern Territory with extensions into Queensland and Western Australia (Plate 2).

Compared with *A. mangium* or

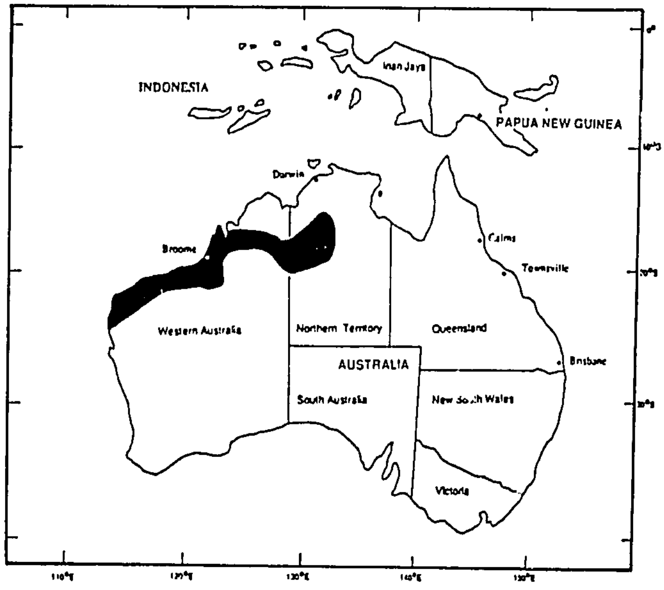

Figure 1. Natural distribution of *A. ampliceps.*

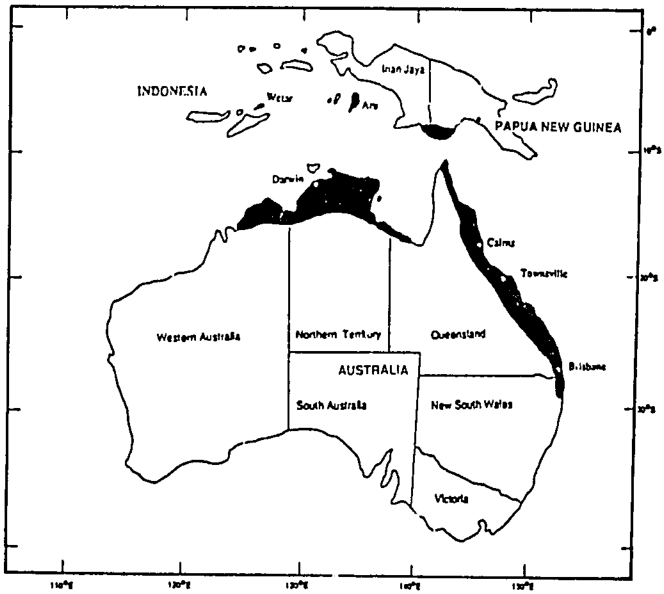

Figure 2. Natural distribution of *A. aulacocarpa.*

Plate 1. A stand of *A. ampliceps* in Western Australia. **Plate 2.** *A. aulacocarpa* in a rainforest in Queensland.

A. auriculiformis, *A. aulacocarpa* is relatively untried. Nevertheless, provenance trials with a limited number of seed sources revealed considerable variation in growth and form (Pinyopusarerk 1989). PNG provenances grew faster and had good stem form, while Queensland provenances grew slower and had a multi-stemmed form. Seedling seed orchards have been established in Thailand and Queensland using seed from PNG provenances.

The present coverage of germplasm of *A. aulacocarpa* is good compared with other species but further exploration and collections are required, particularly in the tropical rainforests of north Queensland.

A. auriculiformis

A. auriculiformis is a well known species, especially in Asia where it is grown for fuelwood, erosion control, and revegetation of wasteland. The species has disjunct distribution in three broad geographic areas: in the north of the Northern Territory, on Cape York Peninsula, Queensland, and in the Western and Central Province of PNG extending across the border into the eastern Irian Jaya (Boland et al. 1990). In most locations, the species grows in narrow strips along river banks or streams, including areas immediately behind mangroves along saline estuaries. In PNG, it is found on the edges of monsoon vine forests and seasonally inundated sites.

A. auriculiformis shows considerable variation in the wild, from single-stemmed trees over 30 m tall (Plate 3) to 10-m stunted trees with less than 1 m in bole length (Gunn and Midgley 1991). Field provenance trials in many countries show that PNG provenances are best for biomass production, and Queensland provenances are best for form while the Northern Territory provenances are inferior in both growth and form (Luangviriyasaeng et al. 1991; Yang and Zeng 1991; Harwood et al. 1991). Geographic variation in seedling morphology has also been demonstrated in a glasshouse study by Pinyopusarerk et al. (1991); there are three distinct groups of provenances which are in accord with the three major occurrences of the species in

Plate 3. Straight-boled *A. auriculiformis* in Papua New Guinea.

PNG, Queensland, and the Northern Territory. The results of the trial suggested that Queensland provenances were more closely related to the Northern Territory than to PNG. Patterns of genetic diversity examined over the range of *A. auriculiformis* using isozyme analysis techniques also revealed three distinct clusters of populations corresponding to the three geographic distributions, with the PNG populations having the highest levels of genetic diversity and the Northern Territory the lowest (Wickneswari and Norwati 1991).

A. brassii

A. brassii is a small tree or shrub with potential for fuelwood or low shelter on infertile, sandy sites. It has a restricted distribution in northeastern Cape York Peninsula north of Princess Charlotte Bay, between latitude 11 and 14°S. Most of the area where *A. brassii* occurs is in the hot humid and subhumid climatic zone. The mean maximum temperature of the hottest month reaches 30°C (Turnbull 1986).

Although *A. brassii* has received little attention so far, it warrants consideration for shade and shelterbelt planting under harsh conditions. It has survived and grown well in areas with a long dry season in Thailand (Pinyopusarerk 1989). Seed availability of this acacia is sufficient for species introduction trials.

A. cincinnata

A. cincinnata grows up to 25 m tall in moist tropics but is a small tree less than 10 m on drier sites. The natural occurrence is confined to the east coast of Queensland between latitude 16-28°S, in north Queensland from Cairns to Mackay and in the south from Fraser Island to Brisbane (Turnbull 1986).

Although not as well-known as *A. mangium* or *A. auriculiformis*, *A. cincinnata* has a range of potential uses, including fuelwood and sawn timber. Its tendency to produce a single stem with good form gives it potential for agroforestry.

A seedlot of *A. cincinnata* from Shoteel, Queensland has shown considerable variation in tree form in field trials in Thailand, varying from multi-stemmed to single-stemmed trees with good stem form. At the Longdong Forest Farm in Guangzhou, China, *A. cincinnata* grows well, with form suitable for posts and poles (Yang et al. 1989). As a result, a seedling seed orchard has been established at the Longdong Forest Farm with genetic material from the species' northern occurrence. Very few provenance collections have been made to date. Priority should be given to obtaining a

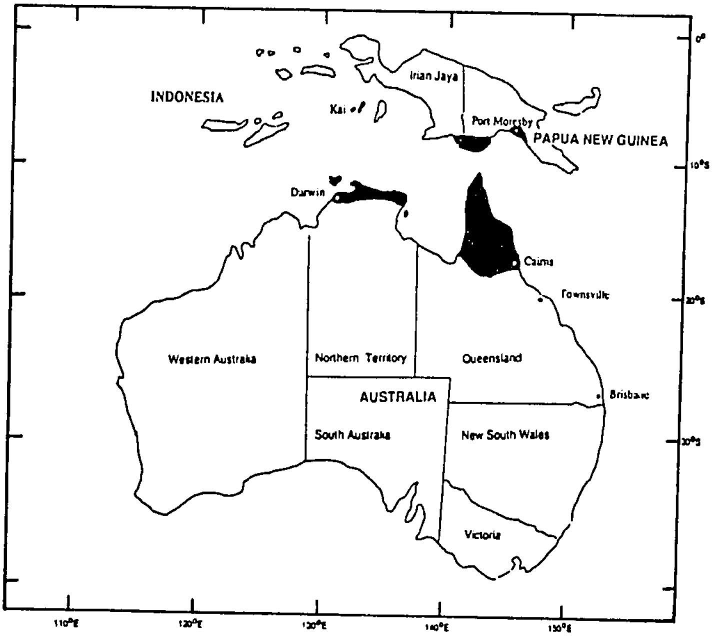

Figure 3. Natural distribution of *A. auriculiformis.*

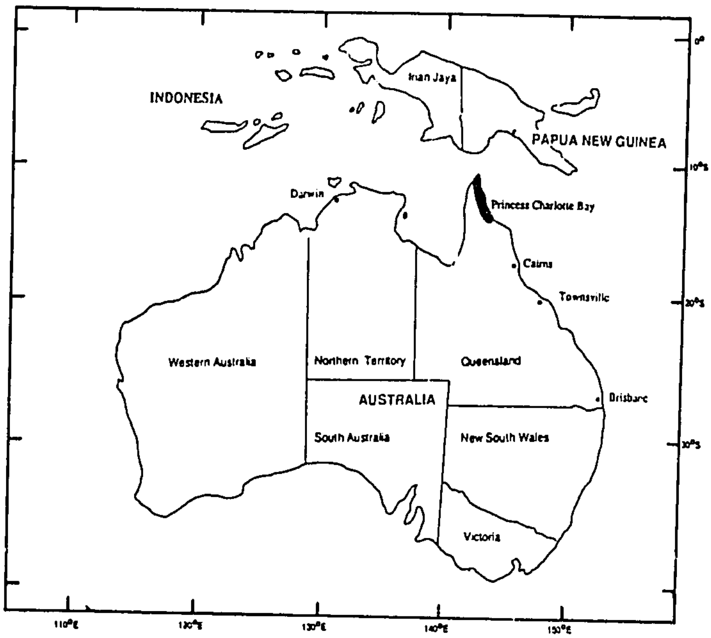

Figure 4. Natural distribution of *A. brassii.*

much wider range of genetic material to allow the potential of this species to be properly assessed.

A. crassicarpa

A. crassicarpa is fast-growing and widely adaptable. It is a small to medium tree 10-20 m tall but occasionally reaching 30 m. Its wood is suitable for heavy construction. Its growth rate has been reported to be twice that of *A. mangium* on poor sites (Sim 1992).

A. crassicarpa is widespread in the Western Province of PNG (Plate 5) and in the adjacent area of Irian Jaya, Indonesia. The species is the most vigorous colonizer on degraded soils following slash and burn cultivation in PNG (Gunn and Midgley 1991). In Australia it occurs only along the east coast in north Queensland from north of latitude 20°S to the tip of Cape York Peninsula. It is also found around Weipa on the west coast of the Peninsula, extending almost to the high tide level. As with *A. aulacocarpa*, the amount of genetic variation in this species has not been fully explored. Available information to date is based on field trials of a limited number of provenances. In general, populations from PNG have been found to out-perform those from Queensland (Harwood 1992). Recent seed collections of this species by ATSC, CSIRO have focused on PNG areas.

Plate 4. *A. crassicarpa* in Papua New Guinea, with clear bole up to half its height.

A. difficilis

A. difficilis, a potentially useful species for fuelwood and erosion control in sandy soils, is a spreading large shrub or small tree up to 10 m in height. It has a compact occurrence in the north of the Northern Territory. It also extends into Western Australia and the extreme north-western corner of Queensland. Latitudinal range is between 11-18°S and altitudinal range is from near sea level to 200 m.

The species is one of the lesser known and information on its performance is restricted to that obtained from a number of species screening trials in Thailand. It has shown adaptability to a range of climatic and soil conditions. It not only survives and grows well on fertile sites with annual rainfall of 1,300-1,500 mm, but also performs satisfactorily on infertile sites with annual rainfall below 1,000 mm and a prolonged dry season (Pinyopusarerk 1989; Chittachumnonk and Sirilak 1991). This species will be an excellent tree for amenity plantings, especially on sandy soils.

A. holosericea

A. holosericea is a species with high potential for fuelwood, soil improvement, and stabilization, and has shown rapid early growth in field trials in Thailand (Pinyopusarerk 1989) and Africa (Gwaze

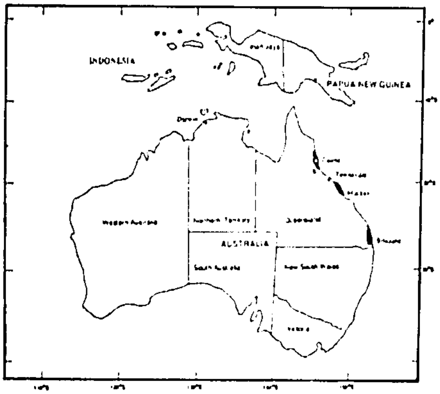

Figure 5. Natural distribution of *A. cincinnata.*

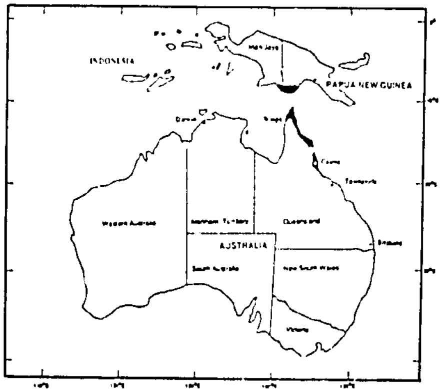

Figure 6. Natural distribution of *A. crassicarpa.*

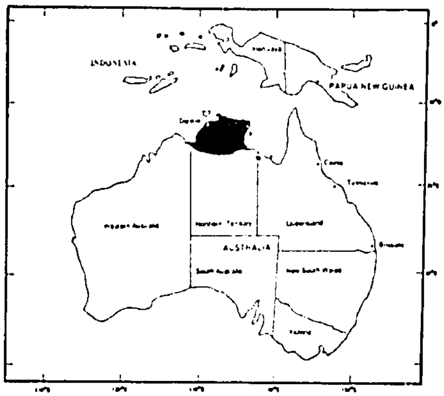

Figure 7.Natural distribution of *A. difficilis.*

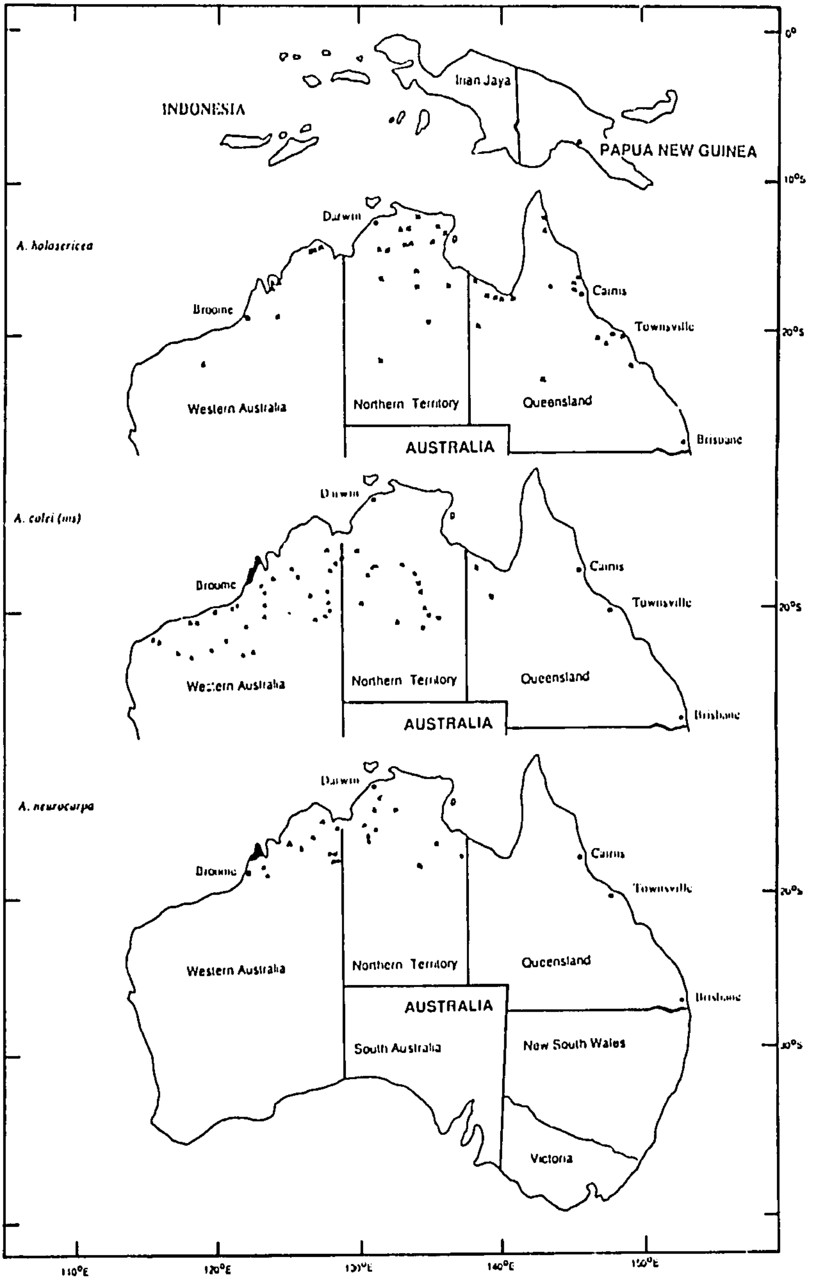

Figure 8. Natural distribution of *A. holosericea, A. colei (ms)*, and *A. neurocarpa.*

1992). It is used to revegetate land after surface mining in northern Australia (Langkamp et al. 1982). More interestingly, seed of *A. holosericea* has been used for human consumption in Niger, Africa (Rinaudo and Thomson 1991), where it has begun to be developed as a significant new food source (House and Harwood 1992).

A. holosericea has a transcontinental distribution in the subtropical dry zone of northern Australia, extending from northern Western Australia to northeastern Queensland. Provenance trials in Zimbabwe showed variation in growth and phyllode color between inland and northern material (Gwaze 1992). An investigation of the amount of genetic variation using starch-gel electrophoresis revealed three distinct isozyme forms (Moran et al. 1992). Chromosome examination showed that the three isozyme forms corresponded to three different ploidy levels, i.e. diploid (2n=26), tetraploid (4n=52), and hexaploid (6n=78) (Moran et al. 1992). These results have led to the recognition of three different taxa: the diploid is referred to as *A. neurocarpa*, the hexaploid is described as a new species *A. colei*, and the tetraploid remains as *A. holosericea* (Maslin and Thomson 1992). Populations of *A. neurocarpa* extend from the west coast of Kimberley region in Western Australia eastward to the Queensland border within the Northern Territory. *A. holosericea* (tetraploid) occurs in populations that are widespread in northern Australia from Western Australia through the Northern Territory into Queensland. The hexaploid *A. colei* MS extends from Western Australia through the Northern Territory to northwestern Queensland with a generally more southerly distribution than the other two species. These three species have different climatic and edaphic preferences with the hexaploid *A. colei* being the most drought tolerant (Thomson 1992b). Figure 8 shows the main area of the species' distribution (reproduced from Maslin and Thomson 1992).

Results obtained from field trials in the Sahelian countries of Africa have shown that *A. colei* and *A. holosericea* have a potential for fuelwood production or environmental protection (Souvannavong and de Framond 1992). Both species are currently used by development projects in Sahelian countries.

A. leptocarpa

A. leptocarpa is a fast-growing small tree to 12 m with great potential for rural forestry. Its propensity to produce a single stem with light crown makes it especially suitable for agroforestry.

A. leptocarpa occurs in Australia and in the Western Province of PNG (Plate 5). It is also found in the Irian Jaya. In Australia, it occurs in a coastal belt from central Queensland to Cape York. It has a

Plate 5. *A. leptocarpa* in Papua New Guinea.

genetic variation in this species has not been fully explored. Available information to date is based on field trials of a limited number of provenances. In general, populations from PNG have been found to out-perform those from Queensland (Harwood 1992). Recent seed collections of this species by ATSC, CSIRO have focused on PNG areas.

A. mangium

A. mangium is the most widely planted acacia, with major areas in Indonesia and Malaysia. It is planted for a variety of purposes including pulp and timber, erosion control and reclamation of grassland (Awang and Taylor 1992).

A. mangium has a fragmented natural distribution that stretches from Indonesia (where it occurs on the islands of Sula, Ceram and Aru) to Irian Jaya, the Western Province of PNG and northeastern Queensland in Australia (Plate 6). Provenance trials established with seed collected in the early 1980s revealed significant differences among provenances in growth performance (Harwood and Williams 1992); PNG provenances grew faster than Queensland provenances while Indonesian provenances grew slowest. Of the Queensland provenances, material collected from Claudie River has shown most promise. Isozyme analysis, however, indicates a low genetic diversity in the species despite its disjunct distribution (Moran et al. 1989), probably because only a small sub-set of the genome was tested. ATSC has made additional seed collections in PNG and Queensland in recent years (Gunn et al 1989; Morse et al. 1991). These have included single-tree collections from several hundred parent trees, thus providing an opportunity for the study of variation at the family level.

A. oraria

A. oraria is a freely-branched shrub with dense foliage up to 5 m tall or widely-branched tree of 10-15 m. It has shown great potential for planting on *Imperata* grassland.

It occurs naturally in northeastern Australia and on the Indonesian islands of Flores and Timor. The main distribution in Australia is from Princess Charlotte Bay to Bowen in Queensland. Some coastal occurrences (e.g., at Port Douglas, Queensland) extend virtually to the high tide level. In Timor it is found at up to 300 m above sea level, and it is recorded up to 700 m in Flores.

A. oraria has not been tested extensively but two Australian provenances differed in their height growth in ACIAR trials in Thailand; a seedlot from Lakeland Downs grew faster than one from Cairns (Pinyopusarerk 1989). Of special note is the high survival rate (>80% in both provenances) and its ability to compete successfully with the notorious weed, *Imperata cylindrica*. Planted at 2 x 2 m spacing, both provenances totally suppressed the grass within two growing seasons. It is thus a species highly recommended for reclamation of grassland, particularly on land abandoned after shifting cultivation in the humid tropics. A wider range of seedlots should be obtained to permit exploration of the species' full potential.

A. plectocarpa

A. plectocarpa is a small slender tree which can grow up to 10 m in height, useful for agroforestry or as a fuelwood tree along farm boundaries in the hot, semi-arid climatic zone.

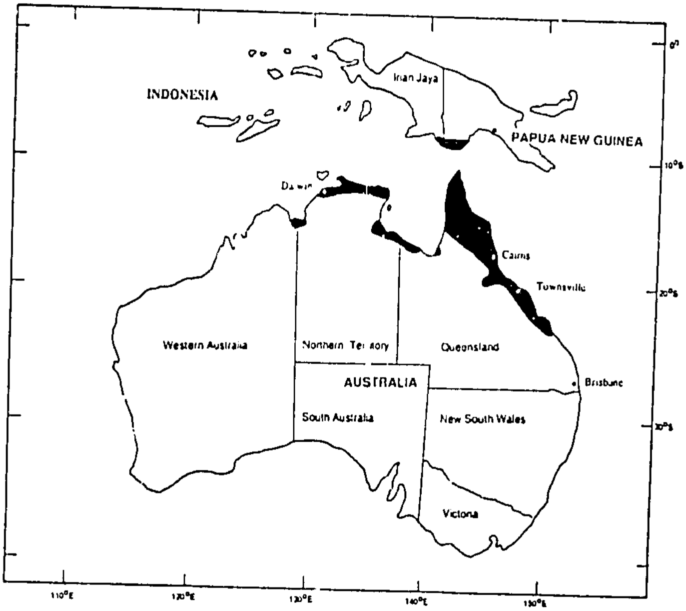

Figure 9. Natural distribution of *A. leptocarpa.*

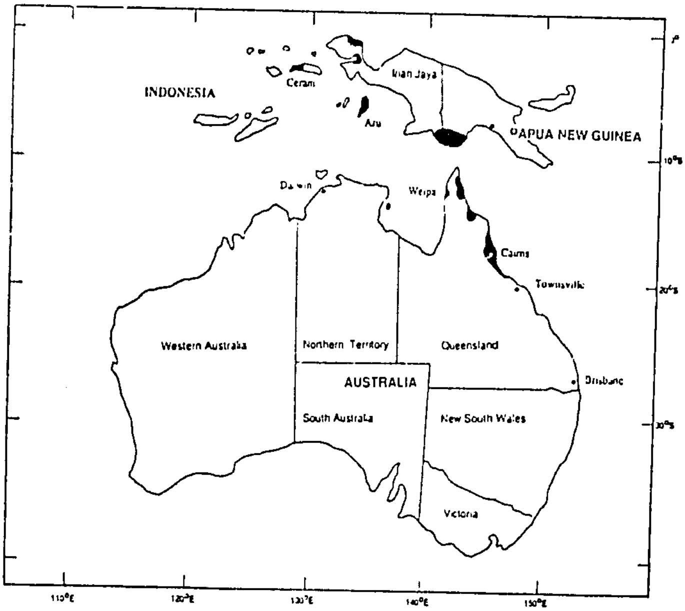

Figure 10. Natural distribution of *A. mangium.*

The natural occurrence of *A. plectocarpa* is mainly in northern Australia in the Kimberley region of Western Australia and in the adjacent northern part of the Northern Territory between latitude 11 and 18°S.

A. plectocarpa is a lesser-known acacia which has not been tried extensively. It has shown better adaptability than *A. auriculiformis* to infertile sandy soils and prolonged dry season in a field trial in northeastern Thailand (Boland and Pinyopusarerk 1987). In that trial, *A. auriculiformis*, widespread in the area, was stunted in growth and severely attacked by defoliators while *A. plectocarpa* grew healthily without insect damage. There was also a considerable humus layer accumulated from litter fall. Thus it too deserves further exploration, especially for revegetation of infertile sites. Additional collections of genetic material are needed, as the current stock held by ATSC consists of only one provenance.

A. polystachya

A. polystachya is a fast-growing tree and is adaptable to a range of infertile soils in the humid and subhumid tropics. It will be a good species for fuelwood and erosion control.

Its natural occurrence is confined to north Queensland, from Cape York to near Cairns, mainly on lowlands near the sea. It is also found on offshore islands from the Palm Island near Ingham to Moa Island in Torres Strait. There have been no reports of the species in PNG.

In its natural habitat, *A. polystachya* varies in form from a bushy shrub 3-4 m tall in open settings to a tall tree 25 m tall in closed forests. It has not been tried extensively and very little is known of the species' performance as an exotic. Seed from a single provenance, Bridle Landing, Queensland, has been included in species screening trials in Thailand. Growth was slow compared to that of *A. auriculiformis* or *A. crassicarpa*, but survival rate was comparable to that of *A. auriculiformis* and higher than *A. crassicarpa* (Chittachumnonk and Sirilak 1991). In general the trees developed multi-stems from near ground level, very often up to 10 stems of more or less the same diameter size. Of special note is the performance of *A. polystachya* recorded at Ratchaburi, Thailand, where the dry season lasts at least 6 months, with high temperatures (absolute maximum up to 40°C) in summer. During the dry season some acacias including *A. aulacocarpa* and *A. crassicarpa* showed sign of yellow phyllodes and shed considerable amounts of phyllodes due to water stress. By contrast, *A. polystachya* was not affected by the high temperature and water stress and retained healthy-looking, dark green phyllodes throughout the same period.

A. polystachya is another lesser-known acacia that should be further tested. At present, seed of this acacia is out of stock and priority should be given to make new collections.

Conclusion

Acacia species are a major source of wood and other products for industrial and rural development and also have a particular role in environmental protection. The full potential of many acacias described in this paper has not yet been tested and warrants further exploration. This can be implemented through existing research networks, such as the Multipurpose Tree Species Research Network supported by the

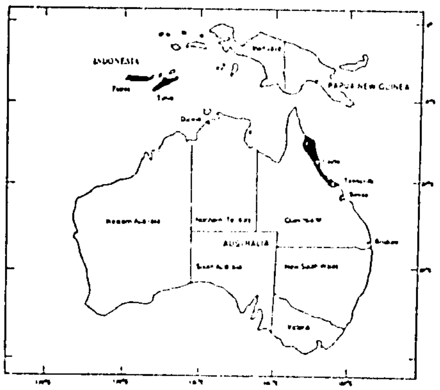

Figure 11. Natural distribution of *A. oraria.*

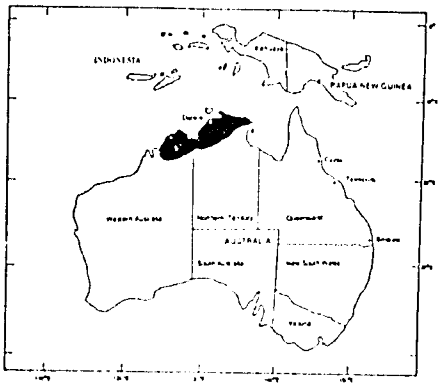

Figure 12. Natural distribution of *A. plectocarpa.*

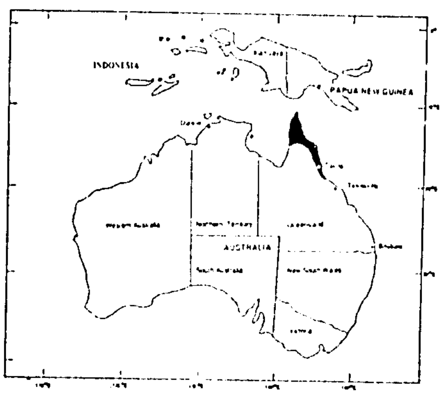

Figure 13. Natural distribution of ***A. polystachya.***

F/FRED Project and the network supported by ACIAR projects.

The genetic material of many *Acacia* species mentioned here need to be sampled more thoroughly. Although ATSC has plans to undertake seed collections of these species, it has existing commitments to supply seed of other genera. Financial support from international aid agencies to set up particular collections may be the solution. The seed collections of *A. mangium* supported by the Food and Agriculture Organization of the United Nations (FAO) in 1982 (Turnbull et al. 1983) and the joint F/FRED-ATSC collections of *A. auriculiformis* in 1987 (Gunn et al. 1988) made possible the evaluation in international provenance trials of these two important acacias. FAO and AIDAB provided financial support in 1991, which enabled collections of dry-zone acacias, including *A. holosericea, A. plectocarpa,* and *A. difficilis* to be made.

Many of the tropical humid *Acacia* species reported in this paper occur in Australia, PNG, and Indonesia. Clearly, the Indonesian genetic resources of these species are the least represented, as most of the genetic material obtained to date has come from Australia and PNG. There would be advantages for Indonesia in participating in future collaborative seed collection and evaluation projects.

Access to remote natural populations of these species is often difficult, and so seed from natural populations is not always available. Establishment of seed orchards should be considered seriously. Seed orchards not only ensure a secure supply of genetically improved seed but also serve as long-term conservation of valuable genetic resources.

Acknowledgments

Most of the distribution maps are reproduced from Turnbull (1986) except those of *A. holosericea, A. colei,* and *A. neurocarpa* which are from Maslin and Thomson (1992). I wish to thank Fiona Chandler for preparing the maps and Chris Harwood and Brian Gunn for their comments on the manuscript.

Discussion Notes

Q: Could you tell us more about the hexaploid *A. colei*? Why was that identified as a separate species from *A. holosericea*?

A: *A. colei* mainly occurs in western Australia and the Northern Territory, in an overlapping but distinct range from the other two species. It is a stable cross of a 2x polyad and another species. Isozyme analysis confirms the determination.

Q: Could you give more information on the potential of *A. leptocarpa* and *A. crassicarpa* in the humid tropics?

A: *A. crassicarpa* doesn't adapt well to long dry seasons (for example, in Chiang Mai, in northern Thailand), but it is good for rapid growth given adequate rainfall and has a high wood density (0.63). We will know more about its performance as an exotic after observing its growth for another 2-3 years.

A. leptocarpa is a small tree. In Sisaket, Thailand, it has shown a superficial root system that requires trenching near agricultural crops. It hybridizes easily with *A. auriculiformis*, and the resulting hybrid is vigorous.

Comment: Generally, it is my observation that fast-growing Australian acacias have aggressive lateral roots, unlike *Faidherbia* (formerly *Acacia*) *albida*.

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Early Growth of Provenances and Progenies in *Acacia mangium* Seed Production Areas in North Queensland, Australia

C.E. Harwood, G. Applegate, K. Robson, and E.R. Williams

Introduction

Some of the best natural provenances of fast-growing tropical *Acacia* species are located in remote areas of northern Australia, Papua New Guinea (PNG), and Indonesia. For example, two provenances of *Acacia mangium* from Western Province, PNG, and Claudie River, Cape York, north Queensland consistently performed best among provenances in an international series of provenance trials of this species (Harwood and Williams 1992). They grew significantly faster than more accessible provenances from the Cairns-Townsville, Queensland area, and two outlying provenances from western Irian Jaya. Similarly, PNG provenances of *A. aulacocarpa* and *A. crassicarpa* have consistently outperformed Queensland provenances in trials in Thailand (Chittachumnonk and Sirilak 1991). Collecting seed from remote natural provenances is difficult and expensive, and not always successful (Gunn and Midgely 1991).

During the period 1988-1991, a total of 25 ha of planted seed production areas (SPA)(footnote: As the stands have been established using unselected individual-family seedlots from the wild, the term *seed production area* is used rather than *seed orchard*(cf. Zobel and Talbert 1984).) of *Acacia aulacocarpa*, *A. auriculiformis*, *A. crassicarpa*, and *A. mangium* was established in northern Australia, with funding from the Australian International Development Assistance Bureau's "Seeds of Australian Trees" project. The main aim of the plantings was to enable secure and continuing production of high-quality seed of superior provenances of these species to help CSIRO's Australian Tree Seed Centre (ATSC) and the Queensland Forest Service to meet international demand for this seed. Results of the pre-thinning assessment of growth and form of *A. auriculiformis* mixed-provenance stand have been published in Harwood et al. (1991). This paper reports the establishment and early growth of *A. mangium* seed production stands, and considers their implications for trial management and genetic improvement.

Experiment Sites

Stands were established at three planting sites in the general vicinity of Cairns, Queenland (Table 1). Soils at Kuranda are red podzolics; those at Cardwell are yellow and red earths; and at Lannercost, grey earths. Original vegetation was open forest to 25 m high, dominated by various *Eucalyptus* species. *A. mangium* occurs naturally in the area, along some rivers and at the margins of small areas of rainforest, but generally not within 500 m of the planting sites, which are separated from each other by at least 200 m of *Pinus caribaea* plantation or natural forest. This relative isolation is expected to

Table 1. Location and climatic conditions* at the three planting sites.

Site	Altitude (m)	Latitude (S)	Longitude (E)	Mean annual temp (°C)	Mean max T, hottest month (°C)	Mean min T, coldest month (°C)	Mean annual rainfall (mm)	Dry season** (months)
Kuranda	380	16°45'	145°30'	23	33	12	1740	4
Cardwell	20	18°24'	146°06'	24	32	14	2110	4
Lannercost	90	18°38'	145°52'	24	33	13	1690	4

*calculated using the BIOCLIM computer program (Booth et al. 1988)
**consecutive months with <40 mm rainfall

minimize *A. mangium* pollen inputs to individual SPAs from external sources.

Sites were cleared, windrowed, and burned in 1987-1990, then strip-mounded by deep plowing. All plantings reported here employed a spacing of 3 m between mounds and 1.8 m between trees along mounds. Randomized complete block designs with 20 replications and single-tree plots were used in all cases. Two external perimeter rows were planted around each SPA. Areas of individual SPAs, including perimeter rows, varied from 0.6-1.3 ha.

Genetic Resources

The approach selected was to establish separate SPAs, each containing a large number of **families**, defined here as trees raised from seed collected from a single parent tree. The families are of course open-pollinated. Each stand incorporated one or more families from each of several **CSIRO seedlots** from within one of five broad **provenance regions**, as follows:

PNG-N:	PNG north of the Fly River
PNG-SE:	PNG south of the Fly River and east of longitude 142°E
PNG-SW:	PNG west of the Fly River and west of longitude 142°E
FNQ:	Far North Queensland (Cape York north of latitude 13°S)
QCR:	Queensland, Cairns Region (latitudes 15-19°S)

The two Queensland provenance regions and PNG are separated be major discontinuities in the species' natural distribution, whereas the three PNG provenance regions are subdivisions of the more or less continuous distribution in the southern part of Western Province, PNG (Gunn and Midgley 1991).

CSIRO seedlot numbers do not always equate with particular, distinct local provenances. In a number of cases, two or more seedlots are collections from the same local provenance in different years (for example, seedlots 17701, 16678, 15677, and 16932 are all samplings of the Claudie River provenance). Because of this, the term *CSIRO seedlot* is used, rather than 'provenance' or 'local provenance,' in the following discussion.

Table 2 summarizes the genetic resources used to establish six *A. mangium* seed production stands in 1991. Four other stands (two of the FNQ provenance region on of PNG-N, and one combining PNG-SE and PNG-SW) were established in 1990 but are not discussed here.

Establishment

Seedlings were raised in the Queensland Forest Service nursery at Ingham, near Lannercost, to a height of 25 cm before outplanting in April-May 1991. Initial field survival was good. A small number of refills (no more than 30 at any one site) were planted in April, June, July, and September at the various sites. The external perimeter rows used surplus *A. mangium* stock of the relevant provenance region.

"Grazon" and "Round-up CT" herbicides were used to control weeds at the Cardwell sites, and "Round-up CT" at Lannercost. No herbicide was needed at Kuranda. All sites received fertilizer, with 100 kg/ha elemental phosphorus as superphosphate. The Cardwell and Lannercost sites also received 5 kg/ha copper as copper sulphate and 5 kg/ha boron as borax. Fertilizer was applied as individual tree applications in a circle of 30 cm radius around the stem 1-3months after planting, except at Kuranda, where half the fertilizer was applied by tractor/spreader 1 month before planting.

Pre-thinning Assessment

Assessments were carried out in September 1992, 16-17 months after planting, when average tree heights were around 3.5-4 m. Tree height and bole length to the first major fork were assessed for five stands. Forking was scored as having occurred when a competing leader was more than half the stem diameter of the main leader. The sixth stand, representing the QCR region, grew more slowly than the others and was not assessed in 1992.

Data Analysis

Height data were analyzed using the statistical package GENSTAT Version 5.2. For each site, plot (that is, single tree) data were analyzed using a fixed-effects model (replicates and families fixed) to estimate family mean heights. The set of family means was then analyzed for significant differences between the CSIRO seedlots. A restricted maximum likelihood (REML) analysis was carried out on the plot data using a mixed model with seedlot and replicate as fixed effects and families random, to estimate family and residual variance components. These values were used to calculate individual-tree heritabilities, using the formula (Zobel and Talbert 1984, p. 255):

$$h^2_i = \frac{4 \text{ x family variance component}}{\text{(family + residual variance components)}}$$

Mean heights at Kuranda and Lannercost of the 44 FNQ families common to both sites were subjected to an across-site analysis of variance using the methods described by Williams and

Table 2. Provenance regions, CSIRO seedlots, and families used in *A. mangium* seed production areas, and mean heights of CSIRO seedlots.

SPA location, provenance region, and CSIRO seedlots		Lat. (°S)	Long. (°E)	No. of families/ CSIRO seedlot		Seedlot mean heights at 16-17 months (m)
Kuranda, PNG-SE						
16592	Mai Kussa R.	8 59	142 15	6		3.98
16585	Bimadebun	8 38	142 03	5		3.84
15642	Boite	8 40	142 00	15		3.81
15644	Oriomo	8 50	143 08	9		4.10
16992	Bimadebun	8 38	142 03	15		3.91
			SPA total	**50**	**mean**	**3.92**
Kuranda, PNG-N						
16938	Kini	8 05	142 58	62		3.16
16939	Duaba	8 13	142 58	3		3.39
16931	Makapa	7 56	142 35	5		3.07
			SPA total	**68**	**mean**	**3.16**
Kuranda, FNQ						
17701	Claudie River	12 45	143 17	28		3.08
16933	Claudie River	12 37	143 20	1		2.69
16678	Iron Range	12 45	143 17	2		3.19
15677	Iron Range	12 43	143 14	10		3.03
15684	Olive River	12 11	142 57	1		3.03
15683	Dulcie Creek	12 02	142 33	1		3.27
16135	Dulcie Creek	12 02	142 33	1		2.84
16932	Claudie River	12 44	142 16	10		3.02
16677	Shelburne Bay	11 59	142 54	6		3.03
			SPA total	**60**	**mean**	**3.05**
Lannercost, FNQ2[1]						
17701	Claudie River	12 45	143 17	26		2.93
16933	Claudie River	12 37	143 20	1		2.43
16678	Iron Range	12 45	143 17	1		2.89
15677	Iron Range	12 43	143 14	15		2.80
15684	Olive River	12 11	142 57	1		2.79
15683	Dulcie Creek	12 02	142 33	1		2.98
16932	Claudie River	12 44	142 16	10		2.90
16677	Shelburne Bay	11 59	142 54	5		2.98
			SPA total	**60**	**mean**	**2.88**

[1] The FNQ provenance region was planted in SPAs at two locations, Kuranda and Lannercost. 44 of the FNQ families were planted at both locations, with an additional 16 planted only at Kuranda and a further 16 planted only at Lannercost.

Table 2, continued.

SPA location, provenance region, and CSIRO seedlots		Lat. (°S)	Long. (°E)	No. of families/ CSIRO seedlot		Seedlot mean heights at 16-17 months (m)
Lannercost, QCR[1]						
15687	S.E. Daintree	16 16	145 22	5		(not yet assessed)
15690	Murray River	18 04	145 53	4		
15693	Lannercost	18 37	145 54	10		
15692	Arnot Creek	18 34	146 11	5		
15678	S. Helenvale	15 54	145 21	3		
15689	S. Edmonton	16 16	145 22	4		
15694	N. Townsville	18 57	146 17	9		
16681	N.W. Ingham	18 34	146 03	3		
16879	NW Kuranda	16 44	145 30	9		
15700	S Cardwell	18 32	146 05	10		
15691	Ellerbeck Rd.	18 14	145 57	8		
16676	S.W. Cairns	17 08	145 45	1		
17703	Tully-Mission Beach	17 55	146 05	27		
			SPA total	**98**		
Cardwell, PNG-SW						
17550	Bensbach	8 53	141 17	23		4.01
16587	Bandaber	8 58	141 19	3		4.13
16584	Bensbach-Balamuk	8 53	141 17	6		4.09
15643	Wemenever	8 43	141 29	8		4.16
16590	Dimisisi	8 31	141 13	7		4.37
16586	Gubam-Boite	8 37	141 55	6		4.28
16990	Derideri	8 42	141 52	9		4.30
16997	Boite	8 37	141 58	12		4.14
16991	Gubam	8 37	141 54	15		4.21
16589	Pongaki	8 40	141 50	15		4.30
			SPA total	**104**	**mean**	**4.18**

[1] The FNQ provenance region was planted in SPAs at two locations, Kuranda and Lannercost. 44 of the FNQ families were planted at both locations, with an additional 16 planted only at Kuranda and a further 16 planted only at Lannercost.

Luangviriyasaeng (1989) and Williams and Matheson (in press). A composite anova table, incorporating the pooled residual mean squares from the two family-level analyses, was used to test the significance of site*family interaction.

Results and Discussion

Table 2 shows mean heights for the CSIRO seedlots at the five assessed planting sites. Early height growth is about 2.5 m per year, with the fastest growth experienced at the Cardwell site. The growth rates are slower than those observed in many Southeast Asian plantings (Sim and Gan 1991; Harwood and Williams 1992). Evidently the intensive site preparation and fertilization used in north Queensland do not compensate for the poorer growth environment, particularly the long dry season and low winter temperatures.

Between-family differences (that is, between families within CSIRO seedlots) were highly significant for all provenance regions (Table 3). The analyses of variance of family values showed that there were significant differences between CSIRO seedlots for the PNG-SE and PNG-SW provenance regions, but not the others (Table 3). Single standard errors for SPAs, to test the significance of individual comparisons between pairs of CSIRO seedlots, cannot be presented because the numbers of families per CSIRO seedlot varied.

Individual-tree heritabilities for the five SPAs ranged from 0.23-0.55 (Table 3).

The SPA with the highest heritability value, PNG-SE at Kuranda, had the smallest residual mean square and was clearly the most effective testing environment for height. The between-CSIRO seedlot differences have been excluded from the family variance component of the heritability estimates (c.f. Atipanumpai 1989). The numerator in the formula used to calculate heritability is the inverse of the average genetic relationship within families. The value used, 4, assumes families are half-sibs. This assumption is unlikely to be correct: selfing and neighborhood inbreeding in natural stands, and full-sib matings within individual pods (Muona et al. 1991) all lead to relatedness among the male parents making up an open-pollinated family. A value of somewhat less than 4 would be appropriate, and this would reduce estimated heritabilities.

The across-site analysis of 44 families common to the two FNQ plantings showed that the interaction between families and sites was not significant (Table 4). This means that family rankings were stable across the two sites. For the FNQ provenance region, families of CSIRO seedlot no. 16677 (Shelbourne Bay) grew as well as those from several seedlots collected in the well-known Claudie River

Table 3. Significance of between-CSIRO seedlot and between-family differences in height and individual-tree heritabilities.

Site and provenance region	CSIRO Seedlots	Families	h^2_i	SE
Kuranda, PNG-SE	**	***	0.55	0.13
Kuranda, PNG-N	n.s.	***	0.23	0.07
Cardwell, PNG-SW	***	***	0.28	0.07
Kuranda, FNQ	n.s.	***	0.36	0.09
Lannercost, FNQ	n.s.	***	0.25	0.08

n.s. = not significant; ** = P<0.01; *** = P<.001

Table 4. Composite ANOVA table for joint analysis of heights of 44 FNQ region families at two sites.

	d.f.	s.s.	m.s.	v.r.	f-probability
site	1	0.5793	0.5793	32.54	***
family	43	3.8313	0.0891	5.00	***
site.family	43	0.7056	0.0164	0.92	n.s.
pooled residual	1634		0.0178		

n.s. = not significant; ** = P<0.01; *** = P<.001

provenance some 70 km away, which comprised all but 2-3 of the other families tested in these two SPAs. This suggests that material from elsewhere in the FNQ provenance region would be worth including in breeding programs that feature Claudie River.

Although it must be kept in mind that these measurements were made on trees only 3-4 m high, these results are encouraging for tree breeders, as they indicate a substantial and stable genetic component in height growth variation of the young trees.

Stem form in these plantings has been poor. More than half of the individual trees are multi-stemmed at breast height. The same *A. mangium* seedlots have been observed to yield mostly single-stemmed trees in a number of plantings in Southeast Asia (Harwood, observations). Clearly, stem form is very strongly affected by the environment of the young plants. Some component of either nursery or site environment, or both, induces forking shortly after planting out. Poor stem form is not directly a consequence of a site having good growth potential, as the Southeast Asian plantings with good form show much faster growth rates than those reported here. Mead and Miller (1991) noted in Peninsular Malaysia a higher incidence of multi-stemmed individuals for *A. mangium* planted on ashbeds derived from burned windrows than for trees planted on the areas between the windrows, and related this to higher phosphorus levels in the trees planted on the windrow sites.

In these plantings, it became clear that the initial spacing of 3 x 1.8 m was too dense to allow the trees to reach sufficient size for accurate selection prior to thinning. An initial spacing of 5 x 2 m would appear satisfactory for *A. mangium*, as it would allow effective selection and access by a "cherry-picker" (a trailer-mounted elevating hoist) between rows for easy seed collection, a necessity in Australia because of high labor costs.

Also, the single-tree plot design used in these plantings was judged inferior to line plots of 4-5 trees. The use of line plots allows efficient within-family selection in the first thinning (by simply retaining the best tree in the line, chosen visually). This ensures retention of all families unless some are purposely removed, and simplifies the thinning of the stand to the planned final density of some 150 stems per ha. Use of line plots enables estimation of the within-plot variance, which of course cannot be obtained from single-tree plots, and when line plots are laid out in incomplete block designs, precise ranking of families is possible.

Still, some genetic improvement in the seed produced by these SPAs may be anticipated relative to seed from natural populations for two reasons:

1. Reduced levels of inbreeding. Each SPA brings together trees descended from many different families from several CSIRO seedlots, some (but not all) of which are separated by distances of 10-50 km and may be regarded as different local provenances. Individual familes were collected in the field at distances of at least 100 m from one another, and are therefore unlikely to be close relatives. The SPAs have been established such that progeny from the same family are never adjacent. These factors should reduce the level of neighborhood inbreeding below that of natural stands.

2. Removal of inferior phenotypes by selective thinning. Selective thinning of the stands at 50% intensity, retaining large, fine-branched trees, was carried out shortly after the assessments reported here. The prevalence of multi-stemming reduced the effectiveness of selection for form. The first seed collections from the stands are anticipated in late 1994, and further selective thinnings will be made on the basis of progeny performance. Large genetic gains from selective thinning are not anticipated because selection differentials are expected to be small.

Separation of the plantings into provenance regions and retention of maternal identity within stands will enable better control of co-ancestry by other groups using the seed in genetic improvement programs. It would be desirable to establish one or more stands in which families from different provenance regions are combined, to take advantage of possible gains from inter-region heterosis (Nikles, in press). This can now be done using retained seed of selected superior families, or clonally propagated material of the best individuals identified in the analyses reported here.

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Discussion Notes

Comment: As Mr. Khongsak noted in the discussion following Mr. Wong's paper, plowing seems to correlate with multi-stemmed form for *A. mangium*.

Q: Will seed produced be made available to scientists in developing countries?

A: As mentioned above, *A. mangium* will start producing in 1994; *A. auriculiformis* has just started; the others are expected to start late in 1993. Research quantities will be available free of charge; for reforestation-scale amounts of seeds, CSIRO will request payment.

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Acacias and Rural Development

H. Arocena-Francisco

Introduction

When I was asked to prepare this paper, I accepted thinking that there were sufficient materials and cases in the Philippines for me to draw on. I found the task more difficult than I anticipated; after a full month of my research assistant's time and some of my own, I am still unable to define in concrete terms the role of acacias in rural development.

My literature search revealed that available references on acacias (most on *A. mangium* and, to a lesser extent, *A. auriculiformis*) dealt with silviculture, tree improvement, and growth and yield studies, with very limited discussions of utilization and economics. Quite a number of materials discuss the potential uses of acacia, but I do not see much point in examining the importance of this genus on the basis of potential uses alone—that would amount to preaching to a group already converted.

Unable to find much of relevance to the topic at hand, I explored another means of gathering information: interviews with people somehow involved or familiar with the extent to which acacias are cultivated in rural communities. The limited investigation I was able to conduct in the time allowed led me to conclude that acacias can indeed play an important role in rural development; there are testimonies that bear witness to this. However, documentation of the experiences of rural communities in tree planting projects is very much lacking in the Philippines, and I will venture to guess in other countries in the region as well. Such studies are important for spreading information on benefits derived by farmers from tree-farming projects with acacias. Documentation of the process by which farmers' cooperation and interest are obtained and sustained would also have relevant lessons for design of future tree-planting projects.

A second difficulty that I realized in preparing this paper relates to the specification of genus and the different ways that different disciplines organize their work. It would have been easier to write on the topic, "Tree Farming and Rural Development" or MPTS and Rural Development" than focus on any specific genus. The basic difficulty stems from the fact that a focus on a particular genus implies a comparison of that genus with other tree species available to the grower. Beyond the local level, this is not an easy job. I decided instead to propose a very simple framework which could be used to evaluate any tree species' contribution to rural development. Using this framework should make it easier to evaluate a tree species or compare several tree species in terms of how well the conditions of their growth and use meet the criteria for rural development as contained in the framework.

The first part of this paper briefly discusses the potentials of acacias in rural communities of Southeast Asia and in the national economics of some Asian countries. Second, it presents examples that point to the realization of these potentials. From this, the paper proposes a framework for evaluating the role of any MPTS in rural development. Finally, the role of acacias in rural development is evaluated using the proposed framework.

Use of Acacias in Rural Communities of Asia

Papers on *Acacia* species suggest the advantages of growing this crop for the country's economy, rural communities, and ecology. Commonly cited attributes of acacias include their wide adaptability to different tropical environments, varying soil types, and degrees of land degradation. Their ability to fix nitrogen in the soil through interaction with symbiotic bacteria (Dela Cruz and Garcia 1992) improves soil fertility, and thus suggests potential in a mix of agroforestry crops. The most visible advantage of acacias lies in their various uses, ranging from timber, pulpwood, and tannin in industry to fuelwood, fodder, food, and shade for rural communities. These products can be obtained in a relatively short time since given acacias' fast growth.

Of the many species in the genus, the most well-known are *A. mangium* and *A. auriculiformis*. *A. mangium* can have straight, light bole suited to industrial demands for furniture, timber, and electric posts. *A. auriculiformis* can also be used as construction material, although its tendency (at least in the Philippines) to form crooked stems makes it less preferred for timber.

A. auriculiformis has a wide-branched habit well suited to meet rural fuelwood requirements. Since this demand can be met by cutting the branches without removing the stems, it is a good species to use against soil erosion and in land rehabilitation, and is widely planted in watershed or water catchment areas. Both *mangium* and *auriculiformis* are good materials for pulpwood.

Given that many farmlands are now considered marginal due to intensive cultivation of even steeply sloping areas for agriculture, acacias are receiving increased attention for their nitrogen-fixing ability and its implications for plant nutrition of nearby agricultural crops. Lack of soil nitrogen is found to limit crop growth, lower the quality of grain or fodder, and even result in crop failure or losses (Brewbaker 1990).

Industrial scale plantation of *A. mangium* started in the Philippines in the early 1980s, about the same time as in Sumatra and other parts of Indonesia (Warren 1990). In the Philippines, the industrial cultivation of *A. mangium* started in the Mindanao region with the electric posts market as the primary end user although some trees are intended as pulpwood. In Indonesia, planting has been concentrated in the lowlands (mainly below 300 m elevation) and is intended mainly for pulpwood and some sawn timber.

Acacias have known potential also as fuelwood, particularly *A. auriculiformis*. Household use of fuelwood can be considered as a form of non-cash income, since its availability on the farm or in nearby farmlots frees farmers from having to purchase it or spend more time in fuelwood collection. The assumption is that time saved in collecting fuelwood can instead be used for productive economic activity.

Rapid forest depletion caused by use of the forest as a fuelwood source for a growing population has been frequently documented. Montalembert and

Clement (1983) estimated that if present trends in population growth, depletion of forest resources, and levels of planting programs continue unchanged, the number of rural people facing fuelwood shortages globally will increase from about 1.15 billion in 1980 to nearly 2.4 billion in the year 2000. Greater farmer participation in fuelwood-growing can be achieved, however, if tree planting is shown to be profitable as well as a means of meeting fuelwood requirements (FAO 1985). *A. auriculiformis* seems to be a good candidate for this role, given its value as fuelwood and its industrial uses such as pulpwood.

Among other non-wood uses, acacias have potential for honey production, in which they provide pollen, the main protein source for beehive nutrition. This could be a valuable source of rural income (Kleinschmidt 1990) but its extent remains unrecorded.

Framework of Analysis: Role of MPTS in Rural Development

The following statement by Hanks (1984) speaks to the role of tree farming in rural development:

> The overall goal of rural development programs should be the reduction of poverty, unemployment, malnutrition and inequity. An integral part of all these programs is the introduction of a positive rural land use strategy, which recognizes the prime importance of food production, but at the same time safeguards the soil and representative areas of natural ecosystems.

This stresses the urgent need to consider environmental protection in efforts to achieve economic growth. With environmentalism growing throughout the world, rural development programs can no longer aim at short-term objectives that may benefit only the current generation. These programs are under increasing pressure to consider the future users of the resource; increasing food production and attaining better access to resources and basic services no longer have the same appeal as before unless attainment of these objectives can be proven to be sustainable. Assuming other things are constant, sustainability of project benefits can be ensured only if the resource base is kept intact or is protected from degradation.

In short, rural development strategies must now be linked to a realistic philosophy of conservation compatible with the goals of poverty alleviation and equitable distribution of wealth. These three necessary elements of rural development programs (poverty alleviation, improvement in access to resources, and environmental protection and/or enhancement) can be found in tree farming projects.

Income Earning Potential of Tree Farming

Much has been written about the success of the tree-farming project initiated by the Paper Industries Corporation of the Philippines (PICOP). In this project, farmers are developing pure stands of *Paraserianthes falcataria* on their own. PICOP is investing millions of pesos in purchases of farmers' harvest of logs for pulpwood. In 1990, the project established 40,348 ha forest plantation, 13,500 ha of agroforestry with 4,400 farmers, and

3,240 ha of social forestry farms involving 1,109 farmer families (Chinte 1992).

The PICOP experience shows that where farmers are linked to a market they will see incentives for investing in tree farms, even if returns from their investment can be realized only after some time. It also shows that farmers' choice of species is closely linked to the existence of a particular market or end user, and can be dictated by the (potential) buyers. This further shows that tree farming can make a better contribution to the welfare of rural communities if they are first convinced of its market potential.

Although it cannot be denied that increasing fuelwood supplies available to rural households is as important in tree programs as increasing household income, experience suggests that focusing tree-growing programs on fuelwood alone have had limited success (FAO 1985). The Wood Energy Program in Malawi provided farmers in areas with perceived wood scarcity with seedlings of fast-growing and high-yielding species. Few farmers became interested in the program, however; only 10% of the seedlings were planted.

An analysis of the problem reveals a discrepancy on the notion of scarcity. To the farmers, fuelwood is not scarce as long as there are places (state forests or communal farms) where fuelwood can still be collected rather than grown. Farmers are not generally interested in planting trees primarily for fuelwood produciton. However, if fuelwood is produced as a secondary product—with higher-value products, such as construction poles and furniture materials of primary importance—then farmers will take advantage of the situation. In Nepal the preferred primary use of the tree can be as fodder.

A recent article in *Farm Forestry News* by Dove (1992) provides evidence from Pakistan that show that for most farmers there, fuelwood is the most important use of trees. Higher-value uses came in second or third in terms of importance. The author concluded that tree programs should not always assume that farmers are interested in growing trees only for the market, but should focus on subsistence-oriented cultivation of multipurpose tree species. My experience with a regional study on farmers' tree-breeding objectives echoes the observation that most farmers see trees as sources of fuelwood (Francisco 1992). Nonetheless, I tend to disagree with the conclusion that, just because farmers' primary use of trees is for fuelwood, they will be willing to grow trees mainly for that use. Although fuelwood is their primary tree use, they can still source fuelwood from elsewhere (even if they have to spend greater time doing it—if there is family labor to spare for it, this is not seen as a problem). Again, farmers may welcome the fuelwood as a secondary product but not feel motivated to plant trees for their own fuelwood consumption. A market for fuelwood, however, may provide enough incentive to grow trees primarily for fuelwood. This reinforces the view that a primary motivating factor for farmers to engage in tree farming is the availability of a sure or potential market for their harvest.

The Farm Forestry Program in Gujarat, India is reportedly one success story where what was intended as a tree-growing project on degraded lands was adopted even on fertile agricultural farmlands once farmers realized that there were markets for construction poles and fuelwood.

Tree farming offers a number of advantages that may not yet be fully appreciated by many farmers. In the long run, tree crops can be more profitable than short-term cash crops, particularly on marginal soils. Trees are also less sensitive to management and market changes since farmers enjoy more flexibility in the decision of when to harvest. Unlike farmers of perishable cash crops, tree farmers can choose to harvest when market conditions and labor availability are favorable. Of course, one disadvantage is that farmers' capital is tied up in trees, which many small farmers cannot afford. Nonetheless, there are different ways to encourage even small farmers to engage in tree farming. Market linkage with companies requiring tree products is the most effective way of encouraging small farmers to grow trees, with financial support in the form of credit.

In general, one can say that a farmer's response to market conditions depends on the magnitude of the expected returns from tree farming compared with those from other opportunities, the resources available to the farmer, and the set of other incentives that go with tree farming (for example, fuelwood supply as a secondary product, or special tree-farming credit).

Income Redistribution through Tree Farming?

Income redistribution is a top priority of rural development programs. In most developing economies, the growing disparity in economic status between the relatively wealthy minority and the poorer majority is bringing increasing pressure to empower the rural poor. Where this growing disparity is resulting in environmental degradation, greater equity is particularly important. This means increasing the access of the rural poor to resources and basic services such as education, health facilities, credit, and infrastructure. It also means providing the poor with greater opportunities for better income by involving them as active partners in the process of development.

The heading above is posed as a question because there seems to be a greater tendency for tree-farming projects to benefit relatively larger farms. Studies have shown that participation in tree-farming schemes is highly positively correlated to size of farm. This is understandable, since trees are usually introduced as part of a farming system that includes cash crops and livestock. Usually, the cash crops are planted on the better soils, while tree crops are planted on marginal sites. On smaller landholdings, fewer trees can be planted.

There are of course mechanisms that can ensure greater participation of small, marginalized farmers. One is the pooling of resources (for example, farmland) by groups of farmers in order to meet the minimum farm size for participation and program benefits. Program implementors may also package income-generating projects with tree-farming programs so that farmers can afford to devote more of their land to trees. Credit and other support incentives can encourage small farmers to participate in a project. These mechanisms point up the need to make extra efforts to involve small farmers in tree programs in which income redistribution is a goal, since greater equity is not a necessary consequence of tree-farming projects.

Environmental Consequences of Tree Farming Projects

Earlier we mentioned that successful rural development programs provide sustained increase in productivity and incomes to low-income rural workers and households. One way of achieving this is through allocation of resources available to the farmers, which can include not only labor and man-made capital assets, but also natural resource assets.

A conventional income accounting system charges depreciation expense for the use of capital assets. This is done to ensure that at the end of the project life of these assets, there will be some amount available for purchasing new assets. The main concern is to ensure the sustainable flow of goods and services provided by these assets. The recognition is growing that we should have treated natural assets in the same manner; that is, depreciation charges against their use should be made if we want to maintain the resource stock (or its capacity to produce natural commodities).

Depreciation of natural assets like farmland can be defined in physical terms as the loss in the productive capacity of the soil resulting from human land-use practices. This loss is normally associated with improper land-use practices or cultivation of crops that exhaust nutrients without a corresponding natural or artificial replenishment. As natural assets depreciate, the capacity of the resource base to sustain productivity is impaired. As a result, whatever initial success may accrue from rural development programs may be short lived.

Conversely, the resource could appreciate if the land use leads to improved soil conditions and enhanced productive capacity. In general, tree farming contributes more to resource enhancement or appreciation than cash crop cultivation. Environmental enhancement benefits not only the tree farmers on-site, but also society at large, even off-site. This is especially true where trees are planted on critical watersheds and on areas subject to heavy soil erosion.

While some tradeoffs between environmental concerns and economic considerations may occur initially, these should be short-term and temporary. In the long run, increased profitability of the farm can only be sustained if the resource base is maintained or is appreciating.

Assessing the Role of Acacias in Rural Development: Empirical Evidence

The framework above is rather general; it simply says that rural development programs must be evaluated in terms of their contribution to the goals of income generation, equity in access to resources, and environmental protection. Another desirable goal is employment generation, which comes under the broader goal of income generation.

Now we will evaluate acacia tree-planting projects on their ability to meet these rural development goals. This section will not be exhaustive; other papers in this volume address different types of projects in greater detail (see the papers by Chung, Adjers, and Subsansenee).

Andin (1980) notes about 1,100 *Acacia* species, found mostly in the dry savannas and arid regions of Australia, Africa, India, and the Americas. In

Southeast Asia, Indonesia and Malaysia have the major *A. mangium* planting programs. In 14 years, that species grows up to 30 m tall with a diameter at breast height (dbh) of 30 cm. Trial plots have been established in many countries. Now, with many plantations and farmlan trees nearing harvestable age, it would be useful to assess how acacia plantations have contributed to rural development under varying environmental and institutional conditions. As Chung (1992) has suggested, the many acacia plantations in Asia may already be facing marketing constraints that could limit the realization of benefits.

Employment and Income Derived From Acacia Tree Farms

Data on the economic profitability of acacias is almost nonexistent in the literature. A personal interview with the manager of a private acacia farm in Musuan, Bukidnon, Philippines revealed the cost and returns information in Table 1 (see Appendix for details).

The 12-ha private farm is owned by a small electric company that services the power requirements of Iligan City in Mindanao. The *A. mangium* plantation began in August 1991. After 10-12 years, based on growth in Mindanao, the firm expects to meet some of its electric post requirements. As of 1993, the firm was buying treated posts at US$240-280 and untreated posts for about US$100 per tree. They expect prices of *A. mangium* to be about $240 per tree after 12 years.

The financial analysis in Table 1 shows that investing in *A. mangium* for electric posts in Mindanao is a very profitable venture, with an estimated return on investment of 64% at 12% and 24%. Excluded in the cost calculations are land rent and harvesting costs, which are not significant enough to affect the expected high profitability. Even if farmers in villages near the power plant were to plant only a few trees in their backyards, they could benefit from the ready market for their produce.

My informant noted that in that area, around 300-400 ha of *A. mangium* have been planted by a number of tree-farming cooperatives. This needs verification. Is the demand for electric posts sustainable? My informant stated that the electric plant changes the electric posts every 10-12 years, creating a perennial demand for acacia posts.

Another key informant from the National Power Corporation Office in Musuan, Bukidnon reported that they have planted *A. mangium* in watershed

Table 1. Cost and returns estimates (USD) for 1 ha *Acacia mangium*, 1991 (discounted values at 12% and 24% over 12 yrs).

Expense	12%	24%
Gross Returns		
Revenue from sale of trees as electric posts, US$20/tree	57,033	16,814
Costs		
Material Costs	481	434
Labor Costs	784	523
TOTAL	1,265	958
Net Returns	55,768	15,857
B/C Ratio	45:1	18:1
IRR	64%	

reforestation projects and have given free seedlings to nearby communities. She noted that the high price of *A. mangium* seeds (US$240/kg) could limit small farmers' willingness to plant the trees unless they are provided free. Both informants noted that small farmers are already planting the species even along farm borders. There is also limited cultivation of *A. auriculiformis*, mainly for pulpwood and household fuelwood.

Acacias and Equity/Access to Recources Issues

Acacias, like any other promising multipurpose tree species, can be intrumental in achieving income redistribution if tree-planting programs ensure participation of the marginal and disadvantaged members of farming communities. Since they are financially handicapped to be active partners in development projects, they will need financial assistance early in the project. However, this should only be for a limited time period since the desired outcome is their self-reliance.

The Philippines has an example of a tree planting program with a strong equity-enhancement component, in which *A. mangium* is the predominant tree species. The program is the Livelihood Enhancement in Agroforestry (LEAF) Program, started in 1991 as a collaborative undertaking by the Andres Soriano Foundation Inc. (ASF), PICOP, and the U.S. Agency for International Development (USAID).

The program is specifically targetting the *kaingineros* of eight upland villages in denuded farlands of a town in Mid-Eastern Mindanao, one of the poorer regions of the country. Its expressed goal is to "improve the socio-economic condition of upland communities through tree farming and creation of income generating projects (IGP)." There are 350 families in 8 farmer cooperatives participating in the program (at least 43 members per cooperative). The program covers 700 ha (2 ha per family); 600 ha are planted with *A. mangium* and 100 hectares to *Eucalyptus deglupta* and agricultural cash crops.

Farmer-cooperators receive funding assistance in the form of grants through their cooperatives. The support covers cost of materials (seedlings, farm tools, and labor). Disbursement follows PICOP's "living tree concept," which finances only trees that are alive at inspection. All of these expenses are to be repaid by the farmers to the cooperative at harvest and placed in what is called a "wood bank" facility. The funds will then be made available to the same farmers (for only 50% of their requirements) and to new farmers for redevelopment and expansion of tree farms until they are self-sufficient. Participating tree farmers also must save 5% of their earnings as a form of capital build-up in the cooperative.

Knowing that farmers will have to wait a long time before they realize returns from their efforts, the program also supports the cooperatives to establish income-generating projects in which members can participate.

It is still too early to assess the program's success. Still, the fact that it specifically addresses the conditions of marginalized farmers on degraded land speaks of the potential role acacias can have in effecting redistribution of income in upland communities.

Acacias and the Environment

The role of acacias in improving soils and forest conditions may be beyond question, for the soil improvement role mentioned earlier. Because of this soil enhancement characteristic, acacias are much favored on marginal lands. Given that, at least in the Philippines, most upland areas are degraded to varying degrees, acacias appear to be suited to the uplands.

Another point that suggests an increasing recognition of acacias' role in environmental protection is their growing use in reforestation projects, as in the Philippines where they are being used to reforest critical watersheds, especially those which provide water to hydropower plants and irrigation systems.

Concluding Statements

This paper has suggested a simple set of criteria by which tree species' contribution to rural development may be assessed:

1. Do the species contribute to realization of higher income (cash and non-cash) by the farm families?

2. Are they being used to redistribute income to the rural poor?

3. Do they enhance the environment to ensure sustainable realization of whatever economic benefits are obtained from the tree farms?

Based on the review of literature and interviews of key informants, evidence tends to support the view that acacias play an important role in rural development. Quantifying the magnitude of this contribution requires greater documentation on the results of programs that have used acacias, as well as the processes by which they have pursued rural development objectives.

Discussion Notes

Q: How practical is the goal of equity as a gauge for forestry in rural development, particularly given the lack of success in other development areas where this has been a goal, and the national need for wood supply that some might say overrides the needs of local communities?

A: The rural poor constitute a growing portion of many countries' population; any economic growth pattern that overlooks their needs is bound to be short-lived and entail a more confrontation when the issue is finally addressed. In upland areas of the Philippines, the rural poor are already occuping forest areas and their presence and interrelationship with the resource cannot be denied. A continued pattern of inequity endangers the stability of that resource base and its future sustainable use.

Q: The return cited for *A. mangium* trees is far greater than that obtained in Malaysia. How can that be accounted for?

A: A specialized market (the electrical authority for poles) and the wide variability in internal rates of return that exist. As Dr. Chung notes, in Sabah sources cite an IRR of 90%; others suggest IRRs of 20%. It varies greatly with locality. It also varies from country to country, depending on the demands of that society.

Comment: *A. mangium* can be treated as poles, but still the pricing is puzzling. Cost of chemical treatment is usually calculated per m^3, and amounts to only 3-4% of the total; labor also normally represents a small portion.

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Appendix: Cost and Return Estimates for 1 ha of *A. Mangium*, 1991

Cost Data (P25 = about USD1):	Year 1	Years 2-5	Years 6-11	Year 12
Seedlings at P10/ seedling at 3 x 3 spacing (1,111 pcs)	11,100	0	0	0
Seedlings during				
replanting, 15%	1,665	0	0	0
fertilizers (10 bags organic manure @ P70/bag	700	0	0	0
Total Material Costs	13,465	0	0	0
Labor Costs				
Land Preparation (2x at P700@)	1,400	0	0	0
Layout (1 man-day)	100	0	0	0
Hole digging at P0.40/hole	445	0	0	0
Planting and fertilizing at P0.50/hole	556	0	0	0
Replanting at P0.05/hole	84	0	0	0
Maintenance Cost at P500/yr for 5 yrs	500	500	2,500	2,500
Farm Manager(part time)	2,500	2,500	2,500	2,500
Total Labor Costs	5,585	3,000	2,500	2,500
Total Costs	19,050	3,000	2,500	2,500
RETURNS				
Sales	0	0	0	6,666,000
NET RETURNS	-19,050	-3,000	-2,500	6,666,000

PRESENT VALUES	at r = 12%	at r = 24%
Material Cost	12,022.32	10,858.87
Labor Cost	19,596.36	13,085.78
Total Cost	31,618.68	23,944.65
Gross Returns	1,710,996.17	504,434.85
NET RETURNS	1,679,377.49	480,490.21
B/C Ratios	53.113458432	20.066704963
IRR	67%	

Acacias in Agroforestry

Goran Adjers and Tjuk Sasmito Hadi

Introduction

There are many definitions of *agroforestry*, but for this paper it is defined as the deliberate combination of trees with agricultural crops or pastures, or both, in an effort to optimize the use of accessible resources to satisfy the objectives of the producer in a sustainable way. The aim of an agroforestry technology is to create an architecture of the above-ground biomass that imitates the climax vegetation of the tropics (that is, a multi-strata forest)(Torres 1989).

Agroforestry systems are commonly categorized by their components—agrisilvicultural, agrisilvopastoral, or silvipastoral.

Agrisilvicultural systems combine concurrent production of food/agricultural crops and trees. In terms of planting niches in the system, trees are located:

- along farm borders (as hedges, living fences, and windbreaks)
- in crop fields (in alley cropping, wide-row intercropping, and as shade, nurse, and support trees)
- around the home (homegarden, shade/ornamental)

There are also agrisilvicultural systems that include pure stands of trees, in which crops are intercropped with young trees for one or more cropping seasons until the canopy closes (taungya). Systems in which trees are planted to improve the soil during fallow periods in shifting cultivation can also be classified as agroforestry systems, since crops and trees are planted in the same piece of land over time.

Silvipastoral systems integrate trees (timber, food, or fodder-producing species) with pasture and livestock. Tree-growing livestock systems can be classified either as fodder banks or pasture improvement. Fodder banks are intensive plantings of fodder trees spaced to maximize leaf production. Trees with nutritious foliage can be planted alone or intercropped with other fodder plants (grasses, for example).

Trees in pastures can enhance livestock production by: increasing grass production in the field; providing fodder directly (from leaves and pods); and providing shade to the livestock, as they digest food more efficiently when shade is available.

Agrisilvipastoral systems combine food crops with trees (for timber, food or fodder) and/or "service" trees and livestock, with or without pastures.

In all agroforestry systems, choosing the proper tree and agricultural crop species is very important. The following criteria are worth considering for planting trees in agroforestry systems (Hegde 1989):

1. Non-interference with arable crops
2. Easy establishment
3. Fast growth and short gestation period

4. Non-allelophatic effects on arable crops
5. Ability to fix atmospheric nitrogen
6. Easy decomposition of litter
7. Ability to withstand frequent lopping
8. Multiple uses and high returns
9. Ability to generate employment

Because it is extremely difficult to find species capable of fulfilling all these criteria, species selection always involves identification of priorities and compromise.

Acacias

Acacia is the largest mimosoid genus of the Leguminosae family, with 800-900 species widely spread in tropical and subtropical regions of the Old and New Worlds (Allen and Allen 1981). Habitats range from arid areas of low or seasonal rainfall to moist forests and river banks. Acacias grow on all soil types and occur in all sizes, from small bushes to large trees.

Despite the large number of species in the genus, only about 75 have proven economic value (as recorded in the literature), and of these, only 50 are cultivated. Acacias provide a wide range of commodities, as described in other papers in this volume.

With so many species in the genus, there are differences in wood characteristics, but in general, acacia woods are coarse-grained, with densities of 640-800 kg/cm^3, highly durable and respond satisfactorily to finishing treatments. A disadvantage is that they are difficult to work. The wood is used for furniture, construction timber, pulp and paper, fuelwood and charcoal. Examples of species with potential for pulp are: *A. auriculiformis, A. decurrens, A. mearnsii, A. mangium,* and *A. mollissima* (FAO 1980; NFTA 1987). *A. mangium* is extensively planted in *Imperata cylindrica* grasslands in Southeast Asia because its rapid growth can quickly suppress the grass.

In agroforestry systems, a main advantage of acacias (and other legumes) is their ability to fix atmospheric nitrogen in the soil. Nitrogen is often a limiting factor for crop growth in tropical soils, so the ability to improve the soil in this factor is beneficial in all cropping systems.

The foliage of many acacias can be grazed and can be an economically important cattle feed. However, pods and leaves of some acacias contain considerable amounts of substances toxic to livestock (Allen and Allen 1981). Some species of acacia produce leaves, pods, or flowers that can be eaten by people, as demonstrated by the Australian wattle cookies and coffee and Thai *A. insuavis* tasted here at this workshop.

Due to the wide range of commodities they produce and their wide distribution, *Acacia* offers a broader range of cultivation options, including agroforestry systems, than many other genera.

Examples of Agroforestry Practices using Acacias

Acacia mearnsii

Acacia mearnsii (black wattle) is native to Australia, mainly occurring in Tasmania and Victoria, where the mean annual temperature is 10-13°C (with a maximum of 20°C) and rainfall is 750-

1000 mm/year (Berenchot 1986).

A. mearnsii is extensively grown in Central Java, Indonesia. In 1922, it was introduced in the tobacco-growing region of Wonosobo, Central Java, at an elevation of 1400-2,100 m asl where temperature varies from 19-12°C and annual rainfall is 3,400-3,800 mm. For more than a hundred years, this region has been one of the most fuelwood-demanding areas on Java. Besides its fast growth *A. mearnsii*'s advantages are its tannin-producing bark (average yield is 35-39% of the air-dried bark), nitrogen-fixing root nodules, and leaves that can be used for fodder and green manure. *A.mearnsii* was quickly accepted and valued by Javanese farmers, and its cultivation was soon adopted by farmers on a rotational system with agricultural crops. Beside tobacco, associated crops include maize, potato, sweet potato, bean, cassava, cabbage, pumpkin, and onion. By 1939, this practice was already widespread.

In Central Java, *A. mearnsii* seedlings are usually gathered from existing stands (wildlings) and established:

- in temporary plots where the tree is used as a fallow crop, followed by agricultural crops for at least as many years as the tree rotation
- in semi-permanent plots, with only one or two years of annual crops between tree rotations. This practice is especially found on steep slopes where annual crops cause severe erosion
- in permanent plots
- scattered on the outskirts of the dry agricultural land (*tegalan*), usually mixed with *Casuarina spp.*, *Schima wallichii*, and *Calliandra calothyrsus*

Fuelwood is the farmers' main benefit of *A. mearnsii* , used mainly for household purposes (cooking and tobacco-curing). The bark's tannin gives additional income. Some farmers compost *A. mearnsii* leaves to fertilize annual crops. When used as a fallow crop, *A. mearnsii* has a soil improving effect. Soil samples taken under *A. mearnsii* cultivation showed an increase in nitrogen (Berenschot et al. 1988).

Acacia nilotica (L.) Willd.

Acacia nilotica (babul) occurs widely on drylands from the Atlantic coast of Africa across the Sahel to East Africa, through the Arabian Peninsula and into northwestern India and Pakistan, where it is one of the most important species. It withstands extreme temperatures (-1 to 50°C), although it is frost sensitive when young. An annual rainfall of 250-2500 mm is required (FAO 1989).

A. nilotica and agricultural crops are commonly planted together in a variety of systems on marginal lands. The most famous is the old practice known as *hurries* in Pakistan, where it is grown on salt-effected lands (FAO 1989; see also the paper by Ansari in this volume).

The rotations used for *A. niloticavary* considerably. A common rotation in Pakistan is 5-6 years, but if there is a great demand for the wood the rotation can be shorter (FAO 1989). The tree can reach an age of 30-40 years, but becomes susceptible to rotting after about 25 years. Annual height growth in dry areas is generally about 60 cm (Kaul 1970), but varies depending on site, with maximum mean annual increments of 13 m^3 at 20 years old and 10.53 m^3 at 30 years.

In India, the Forest Department has arranged with farmers to plant babul in *taungya*-type systems. Farmers lease land for 3 years, growing cotton in the first two years cotton, and sowing babul in rows with cotton in the third. After the third year the land reverts to the Forest Department.

A. nilotica 's products include mine timber and pit props, fuelwood, charcoal, tannin, gum, medicine, fiber, and fodder. The species can grow on saline soils if given sufficient water. If the soil is kept moist until the roots reach the groundwater, the trees can survive even severe drought.

Acacia mangium

The "Reforestation and Tropical Forest Management Project" in South Kalimantan, Indonesia is developing methods for reforesting *Imperata cylindrica* grasslands. *A. mangium* has been one of the main species used by the project, so far on a limited scale.

The experiences mentioned here were obtained from three trials. All three were established in pure *Imperata* sites by mechanical soil cultivation. The soil was plowed twice and harrowed or rotavated once before planting and sowing, and the trees were planted in a 2- x 4-m spacing.

The first trial showed that *A. mangium* height growth at 30 months after planting was slightly better when it was intercropped with watermelon compared to no agricultural crop (251 vs. 256 cm) (Adjers and Luukkanen 1993). Intercropping with peanut yielded shorter seedlings of *A. mangium* compared with no agricultural crop (220 vs. 251 cm).

In the second trial *A. mangium* was intercropped with corn, peanut, and watermelon in combination with two soil preparation treatments: total mechanical cultivation and herbicide spraying. Figure 1 shows *A. mangium* growth in the different treatments.

Yields for both trees and agricultural crops were better in the mechanically cultivated soil. But the experiment showed that spraying also has potential as a land preparation technique. *A. mangium* grew tallest when intercropped with maize, followed by the peanut and watermelon plots.

Survival of *A. mangium* was high in both trials (>95%) and the stand established itself quickly; crown closure occurred at about one year (Adjers and Luukkanen 1993).

The third agroforestry trial aimed to (1) document the effect of intercropped crops on the tree growth, (2) measure yields of the intercrop and (3) assess changes in the nutrient status of the soil (Sabarnurdin and Riswan in press). Four tree species, i.e., *A. mangium, Peronema canescens, Eucalyptus urophylla* and *Paraserianthes falcataria* were intercropped with rice, maize, peanut, and control (no crop).

A. mangium showed the best tree growth, followed by *P. falcataria, E. urophylla* and *Peronema canescens.* Table 1 shows the height and diameter of *A. mangium* in combination with the different crops.

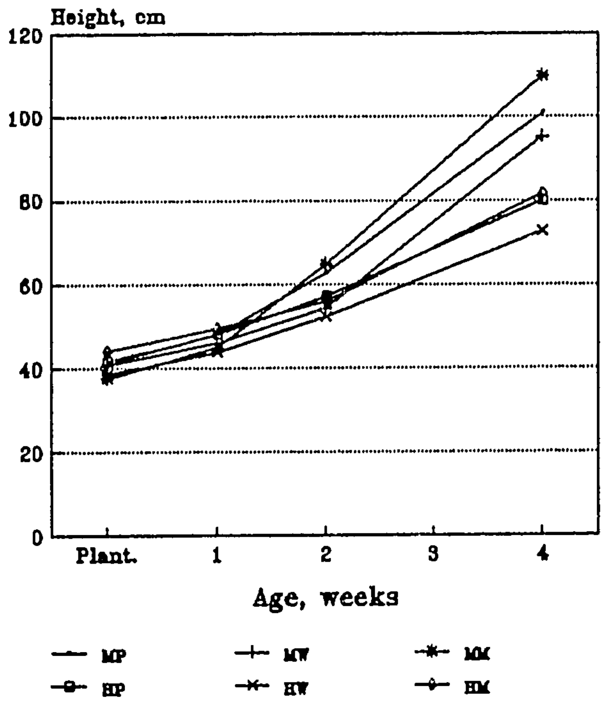

Figure 1. Height of *Acacia mangium* in mechanically cultivated (M) and herbicide-sprayed (H) plots with intercrops of peanut (P), maize (M), and watermelon (W).

Table 1. Average growth of *A. mangium* at 7 months in three combinations, and control.

Treatment	Height (cm)	Diameter (cm)
No crop (control)	239	2.7
Rice	262	3.4
Maize	293	4.1
Peanut	326	4.7

The effect of the tree species to the crop yield is another important result of this trial (Table 2). *A. mangium* seemed to decrease the yield of rice and maize. All other tree-crop combinations gave a better yield than the control. With peanut, however, the plot with *A. mangium* yielded the second best result after *P. falcataria*.

Although seven months is not enough time to make any conclusions about soil properties, the soil properties showed a tendency to improve.

Table 2. Yields of rice, maize, and peanut intercropped with four tree species.

Crop	Tree species	kg/ha
Rice	*Acacia mangium*	1140
	Peronema canescens	2150
	Eucalyptus urophylla	2065
	Paraserianthes falcataria	1955
	Control (no tree)	2250
Maize*	*Acacia mangium*	1900
	P. canescens	2185
	E. urophylla	1965
	Paraserianthes falcataria	2010
	Control (no tree)	2350
Peanut	*Acacia mangium*	1860
	Peronema canescens	1625
	Eucalyptus urophylla	1400
	Paraserianthes falcataria	1900
	Control (no tree)	1675

* calculated from 1 plot only

Acacia auriculiformis

A. auriculiformis is a lowland species occurring naturally in Australia, Papua New Guinea, and in the eastern islands of Indonesia. It is generally a tropical humid and subhumid species that is very adaptable to a wide range of environmental conditions, and has been cultivated as an exotic in Asia, Africa, and South America for more than 50 years. It has been used in all kinds of tree planting programs, including agroforestry.

In agroforestry systems *A. auriculiformis* appears to be used mainly for fuelwood. Its dense wood and high calorific value make it popular for this use. The leaves can be used as fodder and green manure.

Planting *A. auriculiformis* at the border of dry agricultural land and in homegardens with *Cocos nucifera, Cassia siamea, Tectona grandis, Swietenia macrophylla, Arthocarpus sp, Dalbergia sp., Bambusa sp, Musa sp.* and agricultural crops like cassava, beans, and herbs is very common in Central Java (Schreuel and Stegeman 1986).

Other Acacias with Potential for Agroforestry

Much intensive research has been conducted on acacias, both independently and through organizational collaboration in species and provenance trials conducted in Australia, China, Indonesia, Kenya, Malaysia, Pakistan, Republic of China (Taiwan), Shri Lanka, Thailand, and Zimbabwe. These have strongly emphasized Australian acacias.

From an ecological point of view (in terms of preventing epidemics like leucaena psyllid) and from the perspective of local markets and cultural practices, indigenous species of acacias should be promoted in agroforestry systems. So far, however, native acacias have generally received low priority in research. Acacias are indigenous to China, for example, but have not been made commercially important (Wang and Fang 1991). Instead, about 100 Australian *Acacia* species have been tested there, with *A. mearnsii, A. auriculiformis, A. mangium, A. dealbata,* and *A. crassicarpa* expected to have the greatest potential for both forestry and agroforestry (Wang and Fang 1991).

Thailand has 13 native acacias; only

A. catechu and *A. pennata* are planted (Bhumibhamon 1992), but these two are popular and produce marketable products (see the paper by Subsansenee et al.).

Fodder is particularly important in arid and semi-arid areas, where trees can be lopped to feed the cattle during the dry season when other green fodder is scarce. In addition to*A. nilotica*, *A. leucophloea* and *A. planifrons* provide excellent fodder (Singh 1992).

Knowledge is still lacking for many acacias. Available information on acacias in agroforestry can be obtained from the sources listed in the appendix. Streets (1962) also describes a wide range of species grown in the British Commonwealth. NAS (1979) is an excellent source of information on legumes. Other NAS publications focus on more specific topics (NAS 1980, 1983). FAO (1963) contains information on fuelwood species. Turnbull et al. (1986) describes 54 lesser-known Australian species for fuelwood and agroforestry.

Effect of Acacias on Agricultural Crops

Trees and crops planted near each other in agroforestry systems will interact, with the effect varying depending on the species combination, soil nutrient status, competition for water and nutrients, and management system. The effect can be either positive or negative.

The effect of *A. nilotica* on nearby wheat crops was studied by Sharma (1991). Nine-year-old *A. nilotica* planted in a single row 4.75 m apart appeared to have no significant effect on crop height and shoot number, but ear length was greater 8-15 m from the tree line. Furthermore, grains of wheat plants less than 4 m from the trees were significantly smaller, and grain yield increased with distance from the tree line. Yield was significantly greater at >15 m and significantly less at <4 m. In a study in India, *A. nilotica* inhibited mustard crop growth more than *Ziphyphus spp.*, *Azadirachta indica*, or *Eucalyptus tereticornis* (Dalal et. al. 1992). The species' root system competes hard for moisture with nearby crops, a factor that is especially important drier areas.

In Bangladesh, farmers often keep 50-60 trees/ha of *A. nilotica* in sugar cane fields, saying that the trees make the sugarcane grow taller and increase yield. This same tree density reduces yields of rice and wheat, however, so in fields where these crops are grown, the farmers keep only 20-30 trees/ha (Abedin and Quddus 1991).

It may be that, as Harwood notes (see discussion following paper by Pinyopusarerk), Australian acacias (and perhaps others) have aggressive lateral roots that compete with crops more than species like *Faidherbia* (formerly *Acacia*) *albida*.

Growth and yield, litter production, and nutrient cycling for acacia forests and plantations are little understood (Lim 1992). This is even more true about these relationships with agricultural components in a farm system.

Conclusion

Agroforestry is complicated and involves many components. The selection of tree species, crop, livestock, and cultivation system gives many alternatives. The interaction between these components widens the scope of agroforestry research even further.

Professionals with different backgrounds tend to emphasize the aspect of the system closest to their specialization; a forester is likely to be interested in the tree yield, while an agriculturist is interested in the crop yield. To obtain the best possible solution, however, all interests should be considered and the system viewed as a whole.

Economic analyses can perhaps help establish the optimal output of the system, but the local people's participation, preferences, and culture also have to be considered. Many local factors affect decisions about agroforestry practices, and so systems must be evaluated locally. It is a big challenge for research to study all these factors, and requires the involvement of several science disciplines.

Acacias are only a small piece of the agroforestry puzzle. But given the large number of species, wide distribution, and their ability to grow on many types of soil, the *Acacia* genus offers huge potential for agroforestry. Local *Acacia* species, as well as other indigenous nitrogen-fixing trees, offer a range of alternatives.

While the *Acacia* genus has been studied intensively (particularly for industrial plantations) and the availability of information about them makes them attractive alternatives in species selection, the role of acacias in agroforestry still requires much research and development. Even for better known species like *A. mangium* and *A. auriculiformis* information is lacking in this respect. For example, spacing and thinning practices for these species in agroforestry systems are still poorly known.

For lesser known acacias, species and provenance trials and selection must be done, and their role in agroforestry decided later.

Discussion Notes

Comment: *Acacia catechu* is an example of an indigenous species with many niches (see paper by Wanida).

Q: Just a thought: for food-producing tree species, like some dry-zone acacias, does simply growing the tree count as 'agroforestry,' since they provide both food and tree benefits?

Comment: Regarding the need for involving various disciplines, I would like to note that in India, only multidisciplinary approaches are used to study agroforestry, and involve horticulturists, silviculturists, breeders, and social scientists.

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Appendix: Primary information sources on agroforestry species

Organization	Information source
ICRAF	Multipurpose Tree and Shrub Database Library Database Agroforestry Systems Inventory Agroforestry Today Agroforestry Systems
FAO/AGRIS	Database on world agriculture
CAB	Bibliographic database on agroforestry and related topics Agroforestry Abstracts
NFTA	*NFT Highlights* (fact sheets) *Nitrogen Fixing Tree Research Reports* (journal)
USDA/ AGRICOLA	Computerized database covering the holdings of the U.S.National Agriculture Library of the USA

Acacias for Fuelwood and Charcoal

Kovith Yantasath, Somchai Anusontpornperm, Thanes Utistham, Wirachai Soontornrangson and Sutta Watanatham

Introduction

Wood is the primary biomass energy source for over one-third of the human population who use wood as fuel and charcoal for cooking and heating. Nearly 90% of wood consumption in developing countries is for fuelwood. An estimated 50 million ha of additional plantation worldwide is required to ensure fuelwood needs by the year 2000 (World Bank 1980).

In Thailand, over 80% of wood consumption is used as fuel by rural people. Moreover, there is a fuelwood shortage in the industrial sector, particularly in small-scale industries where wood energy is still cheaper than modern energy (i.e., petroleum products). A survey by the Royal Forest Department (RFD) indicated that residental wood energy consumption in 1990 was 2,216 ktoe fuelwood and 1,946 ktoe charcoal (conversion factor for ktoe:fuelwood = 0.37848; charcoal = 0.68364; 1 cu.m. of fuelwood = 0.6 ton; 5 tons fuelwood = 1 ton charcoal). Another survey in 1992 indicated a fuelwood consumption in the industrial sector of 10,800,223 m^3 of wood. An estimated wood energy requirement for the years 1990-2000 is about 22 million tons of wood annually (unpublished data from Thai Forestry Sector Master Plan Meeting in Bangkok 1992 Royal Forest Department).

Tree-planting programs have become major development tasks for governments in many countries, with much effort dedicated to identifying and developing tree species and management techniques for establishment and management of fuelwood plantations.

Species Selection for Fuelwood and Charcoal

NAS (1980) described many fuelwood species by climatic zone. For the humid tropics, many acacias are suitable. *Acacia auriculiformis*, for example, merits large-scale testing as a fuelwood species because it can produce good fuelwood on poor soils, even in areas with extended dry seasons. For tropical highlands, *A. mearnsii*, also a native to Australia, is recommended for poor soils, although it cannot tolerate calcareous soils.

For arid and semi-arid regions with more serious fuelwood problems, *A. brachystachya*, native to vast areas of arid and semi-arid Australia, is considered a superior firewood species, as well as *A. cambagei*. *A. cyclops* can grow in areas with an annual precipitation of less than 300 mm and tolerates salt spray, wind, sand-blast, and salinity. However, this species and *A. saligna* have both proven extremely weedy. In parts of tropical Africa and the Asian subcontinent, *A. nilotica* is a valuable source of fuel, small timber, fodder, tannin, and honey. The plant is exceedingly drought tolerant and survives on many difficult sites, but it is also extremely thorny. *A. senegal*, which although not a fast-growing tree produces excellent fuelwood, is found throughout the Sahelian zone of Africa from Senegal to Somalia.

Research on Acacias in Thailand

Thailand has 13 native acacias: *A. caesia oxyphylla, A. catechu catechoides, A. comosa, A. craibii, A. harmandiana, A. leucophloea, A. macrocephala siamensis, A. megaladena, A. oxyphylla sulonuda, A. pennata, A. podalyriaefolia, A. rugada, and A. tomentosa.* Of these, *A. catechu catechoides* and *A. pennata* are among the more promising planted by rural poor (Bhumibhamon 1992).

With the Australian Centre for International Agriculture Research (ACIAR), the Royal Forest Department introduced Australian tree species for fuelwood and agroforestry testings to several trial sites in Thailand, as well as in other countries in Asia and Africa (Boland and Turnbull 1989). Results from trials planted in 1985 and 1986 showed good potential of *A. crassicarpa, A. auriculiformis, A. torulosa,* and *A. julifera* in terms of fast growth. Provenance variation has been noted for some species; for example, northern provenances of *A. crassicarpa* and *A. aulacocarpa* grew faster than southern provenances. Some species differed in tree from between different sites (e.g., *A. polystachya* and *A. holosericea*) (Pinyopusarerk 1989).

Research of the Thailand Institute for Scientific and Technological Research (TISTR), supported by BOSTID, U.S. Academy of Sciences, showed that *A. auriculiformis* and *A. mangium* had outstanding adaptability to acid sandy soil. They produced wood of high-calorific value and great quantities of biomass (Yantasath et al. 1987, 1992a). Further research by TISTR (Yantasath et al. 1992b) identified drought-tolerant species and provenances tested: *A. leptocarpa, A. auriculiformis, A. crassicarpa, A. plectocarpa, A. holosericea*, and a few provenances of *A. mangium*. At the driest of the four sites, in northern Thailand, *A. leptocarpa, A. auriculiformis*, and *A. holosericea* performed best. Under the wet conditions in the south, *A. mangium, A. crassicarpa, A. auriculiformis, A. leptocarpa*, and *A. difficillis* performed better.

Fuelwood and Charcoal Studies by TISTR

The calorific values of several tree species, including some acacias, have been reported by Harker et al. (1982). Yantasath et al. (1985, 1992a) studied physical characteristics and heating values of several multipurpose tree species (MPTS) including acacias. Described below are results of additional studies of physical properties and calorific values for nine *Acacia* species recently introduced and planted at TISTR's experimental trials (Yantasath et al., 1992b). These nine acacias (*A. difficilis, A. plectocarpa, A. auriculiformis, A. mangium, A. polystachya, A. holosericea, A. aulacocarpa, A. crassicarpa*, and *A. leptocarpa*) were tested for their fuelwood and charcoal heating values as well as for their burning properties. Wood samples at 4 years of age were collected from different sections of the trees-basal, middle, and top. Physical properties and heating values were tested at TISTR's Energy Research Laboratory.

The carbonization temperature used for laboratory charcoal preparation was at 400-450°C.

Wood Tests

Tables 1 and 2 show a wide range of wood density values for the nine acacias (0.3-0.7 g/cm³ based on dry weight). *A. plectocarpa* had the highest values (0.714 g/cm³); *A. mangium* and *A. crassicarpa* had the lowest densities (0.32 and 0.37 g/cm³).

All the species had similar percentages of volatile matter and fixed carbon (70.7-77.7%). The heating values of the different woods were also in the same range (4510-4715 kcal/kg). *A. holosericea* had the highest ash content (1.71%); *A. difficilis* and *A. aulacocarpa* had the lowest (0.64 %).

A. holosericea burned fastest; *A. aulacocarpa* and *A. crassicarpa* burned the slowest (Table 3). After burning, *A. holosericea* had the highest ash content (1.71%); *A. difficilis* and *A. aulacocarpa* had the lowest (0.65 %). From the laboratory testing, *A. plectocarpa*, *A. auriculiformis*, *A. m ngium*, *A. holosericea*, *A. crassicarpa*, and LEP1 showed less than 1% of unburned parts; the others left about 1.5-2%.

Table 1. Physical properties and wood calorific values of nine acacias (based on samples delivery).

Species	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (kcal/kg)
A. difficilis	39.04	46.09	14.48	0.39	2770
A. plectocarpa	28.68	50.44	20.12	0.76	3340
A. auriculiformis	35.45	47.94	15.91	0.70	3040
A. mangium	57.87	31.73	9.95	0.45	1960
A. polystachya	38.87	47.55	13.06	0.52	2760
A. holosericea	36.59	47.06	15.27	1.08	2890
A. aulacocarpa	39.59	45.34	14.68	0.39	2710
A. crassicarpa	52.83	34.05	12.59	0.53	2220
A. leptocarpa	39.92	45.57	13.93	0.58	2810

Table 2. Physical properties and calorific values of nine *Acacia* woods (dry weight).

Species	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (kcal/kg)	Density (g/cm³)
A. difficilis	75.60	23.76	0.64	4550	0.653
A. plectocarpa	70.72	28.21	1.07	4680	0.714
A. auriculiformis	74.27	24.65	1.08	4715	0.604
A. mangium	75.33	23.60	1.07	4655	0.320
A. polystachya	77.79	21.36	0.85	4510	0.648
A. holosericea	74.22	24.07	1.71	4560	0.600
A. aulacocarpa	75.05	24.31	0.64	4490	0.510
A. crassicarpa	72.18	26.69	1.13	4710	0.373
A. leptocarpa	75.85	23.18	0.97	4680	0.495

Table 3. Wood burning properties.

Species	Moisture (%)	Burning time (min)	Heating while burning (Kcal/kg)	Heating (dry wt) (Kcal/kg)	Ash (%)	Unburned portion (%)	Heating efficiency (%)
A. difficilis	9.7	2.9	4110	4551	1.1	1.96	20.6
A. plectocarpa	9.0	2.8	4260	4681	1.24	0.18	25.3
A. auriculiformis	11.1	3.3	4190	4715	1.42	0.18	19.3
A. mangium	10.9	3.3	4150	4655	1.7	0.9	32.6
A. polystachya	11.6	2.6	3990	4511	1.56	0.28	19.5
A. holosericea	10.9	2.1	4060	4561	1.56	0.28	23.0
A. aulacocarpa	10.7	3.4	4010	4494	0.82	1.6	18.6
A. crassicarpa	9.7	3.4	4250	4707	1.0	0.5	16.1
A. leptocarpa	10.2	2.7	4205	4682	1.6	0.23	21.4

Charcoal Studies

A. difficilis and *A. plectocarpa* showed the highest charcoal density by (0.64-0.62 g/cm^3)(Tables 4 and 5). *A. holosericea* produced medium-density charcoal (0.49 g/cm^3) and the lowest density charcoals were from *A. auriculiformis*, *A. mangium*, *A. polystachya*, *A. aulacocarpa*, *A. crassicarpa*, and *A. leptocarpa* (0.2-0.4 g/cm^3).

The volatile matters and fixed carbon percentages of the charcoals were generally similar for all the species tested, with volatile matters ranging 19.27-22.74% and fixed carbon of 74.8-79.2%. As seen in Table 5, the better charcoals with higher ash contents were *A. leptocarpa* (3.24%) and *A. crassicarpa* (2.11%). These two charcoals burned faster; *A. difficilis* and *A. plectocarpa* burned slowest (Table 6).

After burning, both *A. leptocarpa* and *A. plectocarpa* had the highest ash contents, whereby *A. mangium* and *A. aulacocarpa* had the lowest. The test showed that *A. difficilis* charcoal had the most unburned part (14 %). Other species charcoal had unburned parts of 1.1-7.1%.

Table 4. Charcoal physical properties and calorific values (based on sample delivery).

Species	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (kcal/kg)	Density (g/cm^3)
A. difficilis	2.72	21.06	74.82	1.40	7355	0.653
A. plectocarpa	2.65	22.13	72.90	2.32	7110	0.714
A. auriculiformis	2.12	20.51	76.11	1.26	7550	0.604
A. mangium	2.24	19.89	76.22	1.65	7550	0.320
A. polystachya	1.93	18.90	77.71	1.46	7560	0.648
A. holosericea	2.13	21.06	75.01	1.80	7445	0.600
A. aulacocarpa	1.99	20.59	76.16	1.26	7560	0.510
A. crassicarpa	2.78	19.19	75.98	2.05	7450	0.373
A. leptocarpa	1.66	20.19	74.97	3.18	7450	0.495

Table 5. Charcoal physical properties and calorific values (based on dry weight).

Species	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (kcal/kg)	Density (g/cm^3)
A. difficilis	21.65	76.91	1.44	7560	0.646
A. plectocarpa	22.74	74.88	2.38	7300	0.622
A. auriculiformis	20.96	77.75	1.29	7710	0.404
A. mangium	20.34	77.97	1.69	7730	0.317
A. polystachya	19.27	79.24	1.49	7710	0.385
A. holosericea	21.52	76.65	1.83	7610	0.494
A. aulacocarpa	21.01	77.70	1.29	7710	0.459
A. crassicarpa	19.74	78.15	2.11	7670	0.229
A. leptocarpa	20.53	76.23	3.24	7580	0.364

Table 6. Charcoal burning properties.

Species	Moisture (%)	Burning time (min)	Heating while burning (Kcal/kg)	Heating (dry wt) (Kcal/kg)	Ash (%)	Unburned portion (%)	Heating efficiency (%)
A. difficilis	2.72	3.9	7356	7560	3.0	14.1	26.5
A. plectocarpa	2.65	4.0	7109	7302	4.4	5.6	27.6
A. auriculiformis	2.12	3.6	7547	7711	3.3	1.4	28.0
A. mangium	2.24	3.8	7554	7726	2.3	1.9	26.3
A. polystachya	1.93	3.4	7565	7713	2.6	4.1	27.1
A. holosericea	2.13	3.0	7446	7608	3.5	4.2	30.2
A. aulacocarpa	1.99	3.2	7559	7713	2.3	7.1	27.7
A. crassicarpa	2.78	2.9	7454	7667	3.0	1.1	26.5
A. leptocarpa	1.66	2.7	7450	7576	4.4	2.1	28.3

Carbonization yields of acacias under 3 hours with temperature maintained at 400-450°C (Figure 1) showed that *A. plectocarpa* had the highest yield (40%).

Conclusion

The tested woods with fast-burning properties were *A. auriculiformis, A. polystachya*, and *A. leptocarpa*, followed by *A. difficilis, A. plectocarpa, A. mangium, A. aulacocarpa*, and *A. crassicarpa*. Slow and complete burning of woods resulted in high fuelwood efficiency. Wood with higher ash content gave higher calorific value than wood with lower ash. Charcoal from *A. holosericea* showed highest heating efficiency (30.2%) compared to other species. *A. mangium* charcoal had lowest heating efficiency, with 26.3%.

Compared with other MPTS used for fuelwood, these acacias show high calorific values and high biomass production. Furthermore, they adapt well to most acid, poor tropical soils and thus could play an important role in addressing the increasing demand for fuelwood in tropical countries.

Discussion Notes

Comment: Markets for fuelwood and charcoal can be rigid for reasons of local preference, as well as stacking, heat release, etc. For this reason, marketability should always be viewed from the outset, and opportunities should be explored for improving species already used for these purposes locally.

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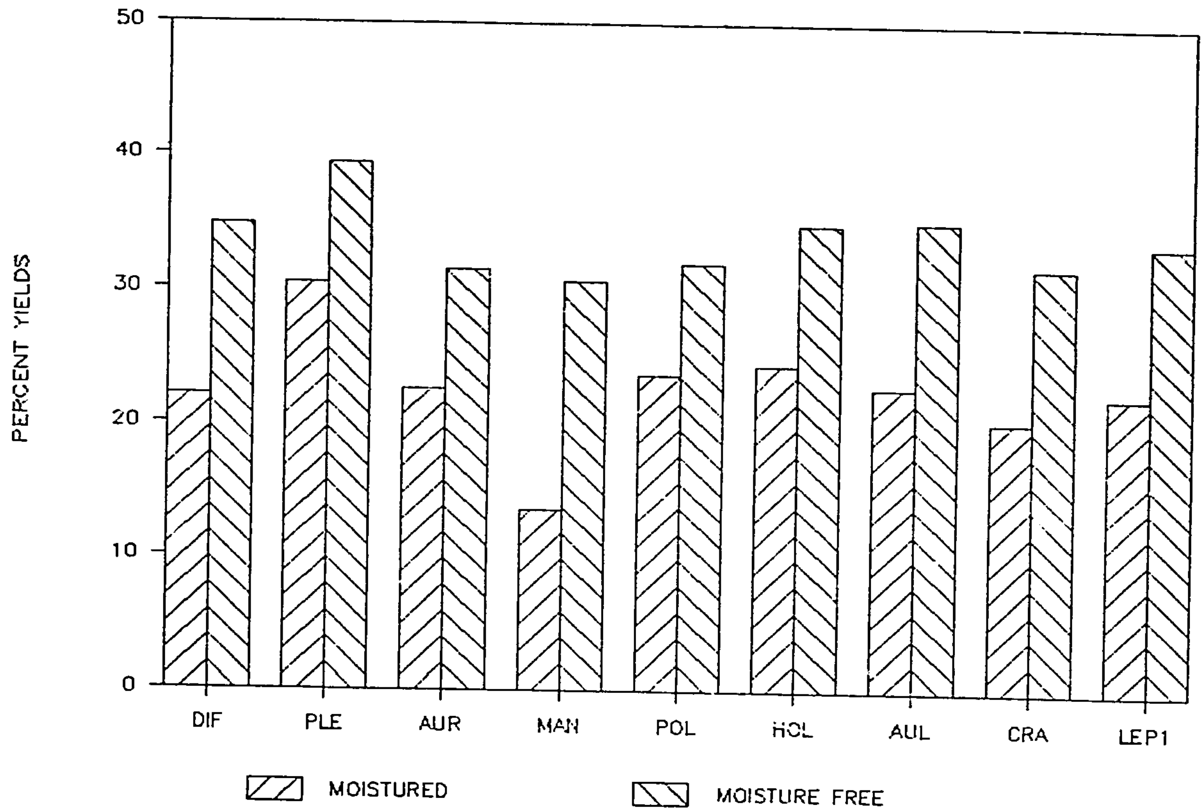

Figure 1. Carbonization yields at 400-340°C, maintained for 3 hours.

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Utilization of *Acacia catechu* Willd. in Thailand: Improving a Cottage Industry

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Introduction

The non-wood forest products available from tropical forests are often hidden or neglected. This paper describes a research project that aimed to improve the value of non-wood products from *Acacia catechu* in Thailand in view of their value in India. The authors and the U.N. Food and Agriculture Organization (FAO), which funded this research, hope that this paper will serve not only as a technical guide for *A. catechu* utilization, but also as an example of how the value of non-wood forest products can be highlighted through improvement and development of processing techniques. Production of value-added products, as cottage industries and on a large scale, can help people realize the value of tropical forests and lead to more realistic conservation of tropical forests and sustainable rural development.

A. catechu is valued in India for the role its heartwood in making *katha* and *cutch*, two commercially important products. *Katha* is a key ingredient of pan and pan masala, which in South Asia are traditionally chewed after meals. *Cutch* is used as: a **tanning agent** for leather; a **cheap dye** for canvas, fishing nets, mail bags, etc.; and in oil-well drilling as a **viscosity modifier** of drilling mud. Consequently, *A. catechu* wood is considered an important industrial material and fetches as much as US$240 per m^3 in India.

A. catechu also grows in natural forests and plantations in Thailand. But there its utilization falls far short of the potential. Although the wood can be used in making furniture and is an excellent source of fuel and charcoal, its price is much lower than in India, and is consumed mostly as fuel sold at 150-300 Baht/m^3 (US$6-12). Only a small portion of the country's *A. catechu* resource is used in the extraction of *crude cutch* by small cottage industries in northern Thailand, where the indigenous technique and method of extraction is still inefficient compared to that in India. The extract is not purified, and receives only 20 Baht per kg (US$0.80) in the market. The more refined cutch that serves as a tanning and dying chemical is also extracted in Thailand, mainly for dying fabrics a black or brown color, or staining wood, but also as a tannin, and medicinally as an astringent for diarrhea and soar throat because it contains gum catechin, catechu tannin acid, catechu red and quercetin.

In view of the proven market potential of *A. catechu* products in South Asian countries, the Non-wood Forest Products Research Section of the Forest Products Research Division in RFD aimed to explore appropriate and advanced technology to improve the use of the *A. catechu* resources in Thailand. Specifically, RFD aimed to improve the domestic production system for higher quality crude cutch in the rural cottage industry, and also to encourage establishment of a large-scale extraction factory for katha, cutch, and other promising products.

The RFD scientists consulted Dr. Y.S. Rao, then Regional Forestry Officer of the FAO Regional Office for Asia and the Pacific (FAO/RAPA) in Bangkok, and with his strong support and guidance launched an FAO Technical Cooperation Project (TCP) called "Chemical Processing and Utilization of *Acacia catechu* (TCP/THA/6769)", under the spirit of Technical Cooperation between Developing Countries (TCDC). The project sought to transfer appropriate technology from India to Thailand.

RFD and FAO agreed to conduct basic investigations and exploratory experiments on a laboratory scale before initiating pilot plant studies. A nationwide *A catechu* resource inventory was carried out, which included ecological and silvicultural studies. The cottage industry practiced in Lampang province in northern Thailand for extracting crude cutch was investigated. Also, an RFD *A. catechu* plantation in Nakhon Ratchasima province in the Northeast was selected to study growth patterns and proportion of heartwood of trees of different sizes and ages. This plantation also provided materials for the experiments in RFD's laboratory.

The inventories, field work, and laboratory work took time. Dr. K.S. Ayyar, an Indian chemical researcher, visited Thailand for several months to provide the Thai researchers with technical skills. Two Thai researchers also travelled to India for further training and field visits. All the substantial technical and financial assistance was provided by the FAO project, with Mr. M. Kashio, Regional Forest Resources Officer of FAO/RAPA, providing technical and operational support.

This work earned the RFD research team an honorable award for "most significant research work of the year 1988," given by the Director General of RFD. Research has continued, and though results have been presented in academic forums, only recently have the complete results been prepared as an FAO publication (Subsansenee et al 1992). It is hoped that this work will encourage pilot-plant studies and the establishment of industrial-scale utilization of *A. catechu*, as well as improvement of the domestic cottage industry. Together these could make an important contribution to rural and economic development.

Basic Facts About *A. catechu*

Botanical Description

Acacia catechu, commonly called "cutch tree" or "catechu tree" (Table 1), is a moderate-sized, deciduous or semi-deciduous leguminous tree. It attains a cylindrical stem up to 50-150 cm in girth with a 6-m bole and 10-15 m total height. It has a clean crown and sharp thorns on its stem and branches. The

Table 1. Common names of *A. catechu*.

Common names in Thailand	Trade names
Sa-che (Shan Mae Hong Son)	Cutch tree
Seesiat (Northern Thailand)	Catechu tree
Seesiat kaen (Ratchaburi)	Khair
Seesiat nuea (Central Thailand)	(in India)
Seesiat lueang (Chiang Mai)	

dark grayish brown bark is nearly 1 cm thick, exfoliating in long narrow strips, the backside of which is brown or red in color. The leaves are bipinnate, 9-17 cm long, with numerous small, sessile leaflets. The stipules are often modified into pairs of thorns at the base of the petiole. The small yellow or pale yellow flowers are auxiliary cylindrical spikes, 5-10 cm long. The calyx is bell-shaped and divided into five lobes as well as corolla. The stains are free and numerous. The fruit is in long, straight, flat pods 5-10 cm long, smooth and pointed at both ends. The mature pod is dark brown and longitudinally dehiscent, with 3-10 seeds.

The sapwood is creamy white in color. The heartwood is brown and turns black on exposure. It is very heavy and odorless. In some trees one can see white powdery deposits known as *keersal*.

Ecology and Distribution

A. catechu occurs widely in the drier areas of India, Myanmar (Burma), and Thailand. In the forests of India, *A. catechu* is a small tree, 12-15 m in height (a bole of 2-3 m and usually crooked) and 60-90 cm in girth, with a light feathery crown and dark brown, glabrous, slender, thorny, shining branchlets. There, three main varieties are recognized:

- var. *catechu*, which predominates in Jammu, Punjab, Uttar Pradesh, Madhya Pradesh, Bihar, and as far south as Andhra Pradesh and Orissa, but has never been found in the Eastern Himalayas
- var. *catechuoides*, which predominates in the Eastern Himalayas
- var. *chundra* (syn. *sundra*), confined to southern India

Thus, *A. catechu* is widely distributed throughout most of India except the most humid and driest regions. It is common in the sub-Himalayan tract and outer Himalayas ascending from 900 m to 1,200 m from Jammu to Assam.

Resources in Thailand

In Thailand, *A. catechu* occurs in mixed deciduous forests, and grows best in open, dry places. It prefers light and good drainage, but can grow on almost any soil, even on environmentally poor sites where few other species survive. including arid, shallow, stony soils, and even on sheet rock. The tree coppices well.

Natural stands of *A. catechu* have become very scarce in Thailand, mainly because it has been over-utilized. Large mature trees and even small ones are cut or destroyed by fire. Natural regeneration is rare due to a shortage of seed trees, degraded soils, and other environmental changes unfavorable to this species.

In 1959, the Thai Government began to plant *A. catechu* for fuelwood supply and medicinal uses. According to a nationwide inventory carried out under this project, *A. catechu* plantations cover some 3,470 ha in the provinces of Chai Nat, Chiang Mai, Chiang Rai, Chonburi, Kanchanaburi, Lampang, Loei, Nakhon

Table 2. Estimated plantation resource of *A. catechu* in Thailand.

Province	Age classes (years)	Number of trees	Area (ha)
Chai Nat	1 - 5	10,000	48
	6 - 10	9,000	24
	11 - 15	84,000	64
Chiang Mai	6 - 10	582	6.4
Chiang Rai	16 - 20	500	1.6
Chonburi	6 - 10	3,100	5.6
Kanchanaburi	11 - 15	65	0.2
Lampang	1 - 5	2,750	22.4
	6 - 10	1,800	16
	11 - 15	1,500	14.4
	16 - 20	750	11.2
Loei	6 - 10	120	0.2
	16 - 20	2,400	8
Nakhon Ratchasima	1 - 5	26,100	24
	6 - 10	115,767	256
	11 - 15	22,000	96
	21 - 30	156,450	1,264
Ratchaburi	16 - 20	26,600	278.4
Saraburi	11 - 15	396,755	713.9
	16 - 20	72,400	211.2
	21 - 30	128,400	392.8
	> 30	1,500	9.6
Total		1,062,539	3,467.9

Source: Provincial Forestry Offices, RFD, 1988-1989.

Ratchasima, Ratchaburi, and Saraburi (Table 2). All these plantations are on government land. There are also some small, privately owned plantations in Chiang Rai province in northern Thailand that produce crude cutch.

Utilization in India

As mentioned earlier, the heartwood of *A. catechu* is the raw material for making katha and cutch. High-quality katha (or "cutch-free" katha) is light brown even after prolonged exposure, and fetches the highest price in the Indian market (about US$15.20-15.60 per kg). The price decreases as the color deteriorates to dark brown or black, with inferior quality katha fetching only about US$2.40 per kg. The price of cutch is about US$0.80 per kg.

How the Resource is Managed

Due to its high value locally, *A. catechu* is carefully managed using silvicultural treatments. In moist forests, the size preferred for katha manufacture is 30-35 cm in diameter. Exploitable diameters of 30 cm for bhabar forests and 35 cm for tarai forests of Uttar Pradesh State are often prescribed, with a felling cycle of 10-30 years. In the dry peninsular forests of Uttar Pradesh, working under selection felling, the exploitable diameter is as low as 10 cm.

Branches having a heartwood diameter of at least 2.5 cm are also used to obtain katha. Freshly felled trees give the highest yields; dead trees are unsuitable as their katha content is less than that of freshly felled trees of the same age. Gnarled and crooked trees are believed to give better katha yields.

Extracting Katha in the Indian Cottage Industry in the Forests

Cottage industry operations in the forests of India continue to produce katha and cutch, although there are now a number of large-scale factories in the country that manufacture these products. The main operations in the cottage industry are:

(1) extraction of the wood with water
(2) concentration of the extract to crystallize katha
(3) filtration of katha
(4) drying of katha
(5) preparation of cutch

The first two operations are done simultaneously, usually in earthen pots arranged in parallel rows on a long shallow fireplace, or *bhatti* (Plate 1). The pots in the side rows are used for extraction, while concentration is carried out in the central rows. The concentrate is transferred into wooden vats and the katha is left to crystallize. The filtration of the separated katha takes place in huge pits lined with gunny bags. The "mother liquor" containing cutch gradually soaks into the earth, leaving katha as a semi-solid mass in the gunny bag filters. Subsequently, the semi-solid katha is dried on sand beds, cut into small cubes with wooden knives, and allowed to dry in the shade. In the Indian processing method, cutch is not isolated from katha and totally wasted. This traditional process for producing katha has been improved by the Forest Research Institute at Dehra Dun.

The large-scale factories that produce katha follow the same principles of production employed in the cottage industry, except that the operations are mechanized. Most of these factories can process 20 tons of chips per day.

The Situation in Thailand

Traditional Uses by Communities

As mentioned earlier, *A. catechu* wood is sold in local markets in Thailand as fuelwood and as material for charcoal making, at a price of 150-300 Baht/m^3 (US$6-12). The bark is sold for medicinal purposes at a price of about US$0.32 per kg and is used as an antidysentary and antidiarrheal, and also for healing wounds. The seeds are used as an antibacterial medicine.

Crude Cutch Production by Family Operations

In northern Thailand, crude cutch is produced in family-run cottage industries under the following conditions, using trees purchased at a price of US$12-14 per m^3:

1. Site and Area:
The cottage industry is run in private homes and requires only a small area.

2. Seasonality:
Five months from December to April (from the middle of the cool season through the hot, dry season).

3. Raw Materials and Transportation
The operation uses catechu trees growing near the home, either in the natural forest or in plantations. The trees are transported from the forest by carts, which can normally carry only about two logs. Because of the short distances, however, transport cost is estimated at about US$1.60 per cartload.

4. Labor Requirement:
The entire work is done by family members (usually two persons). No external labor is employed.

5. Equipment/Materials:
2 shallow vessels made of an alloy-pan, capacities of 60 and 40 *l*
1 long-handled knife
Planks of rain tree (*Albizia saman*), c. 15 cm wide x 2.5 cm thick
1 bamboo cylinder almost conical in shape (open at both ends, and about 15 cm in diameter)
1 dipper
1 small paddle
1 fireplace
1 stick lac
1 hand axe
1 bamboo basket

Processing Method and Techniques

The chips are extracted in the shallow 60-*l* iron alloy vessel. It is set directly over a fire, then coated with the resinous lac to a thickness of about 0.5 mm. The bamboo cylinder (Plate 2) is then set in the center of the vessel, with about 45 kg of chips packed around it, up to 2-3 cm from the edge. The chips are heaped in a conical shape from the periphery of the iron vessel to the top of the bamboo-cylinder. Put 30 *l* of water in the vessel and cover the top of the chips with the rain-tree planks.

The iron vessel is heated until the volume of water decreases to 10 *l*. Any type of fuel may be used, including sapwood or small branches of cutch trees. The hot extract is removed and put into the second shallow vessel of 40 *l* capacity (Plate 3). This is repeated seven times, and takes about nine hours. The whole extraction operation, including the time needed to attain the correct consistency, takes a total of 11 hours. Obtaining the correct concentration is a tricky operation that requires experience. It is not controlled by any scientific measurement or the specific gravity.

The concentration extract is cooled, rolled into balls, and dried (Plate 4). There are two sizes of balls: 2.5 cm and 5 cm in diameter. The smaller size is for the Thai market, and the larger is for export to India and Pakistan. The exhausted chips are sometimes burned as an insect repellent to protect the family's cattle.

Plate 1. The shallow fireplace, or *bhatti* , in which the the first two stages of katha and cutch extraction take place in the Indian cottage industry.

Plate 2. The cylinder made of bamboo strips.

Plate 3. In the Thai cottage industry, two metal pans are used: one is for boiling the extract, the second is for cooling the concentration.

Plate 4. The concentration extract is cooled, rolled into balls, and dried.

Cost-Benefit Analysis

A simple costs-and-returns analysis was made to assess the economics of the crude cutch cottage industry in Lampang. The result is summarized in the following.

Production Costs (per extraction):

a) 45 kg of chips (a half wood of 60-80 cm in girth):	US$0.70
b) Transportation cost of the wood mentioned above:	US$0.40
c) Fuel for extraction:	US$1.22
d) Water for extraction (10 Baht/200 *l*):	US$0.40
e) the depreciation of equipment and other incidentals:	US$0.08
Total	US$2.80

Returns: About 6 kg of crude cutch is extracted at one time. Since the selling price of crude cutch is US$0.80 per kg, the total sale from one extraction is: US$4.80

Net Returns: The net returns for each extraction are, therefore, US$4.80 - $2.80 = $2.00. The ratio of net returns over investment per extraction is as high as 71.4%.

Quality of the Crude Cutch

Dechatiwongse and Jewvachdamrongkul (1986) analyzed the quality of the crude cutch produced, commonly called "black catechu" in Thailand. They collected four samples of black catechu: one from a local factory in Lampang province, and three others from shops in Bangkok. As shown in Table 3, the quality of the black catechu from Lampang met medicinal standards (Indian Standard Institution 1964, 1967, 1969). The three samples from the shops in Bangkok did not meet these requirements, indicating that the quality of black catechu currently produced and marketed in Thailand is not consistent for medicinal purposes.

Laboratory Studies on Processing

Determining the Threshold Age for Extraction

Before embarking on large-scale exploitation of *A. catechu* for katha,

Table 3. Quality of crude cutch (black catechu) in Thailand.

Sample origin	Loss in drying (%)	Ash (%)	Insoluble in alcohol	Insoluble in water	Catechol-tannin
Lampang factory	6.49	3.02	20.99	14.82	21.50
Standard	≤12*	≤3** ≤6*	≤40*	≤25* ≤30**	≥20**

*The Pharmacopoeia of India; **Yunnan Provincial Standardization of Pharmaceutical Products crude cutch, and cutch, availability of raw materials must be assured for at least 25 years. Investigations need to establish the minimum age or girth class of the tree for economical returns, and to identify which parts of the tree can be used in the extraction of the three products

Selecting Trees for Extraction

To ascertain the quantity of heartwood and its katha and cutch contents for trees of different age and girth classes, *A. catechu* trees of three classes (five trees each of 10, 15, and 20 years old) selected at random from the RFD plantation in Pang-asoke District, Nakhon Ratchasima province. The total extractives of each tree were determined. Chips of each tree (50 g) were extracted in boiling water (chips:water ratio of 1:2.5) for 2.5 hours and filtered while hot into a volumetric flask. After it had cooled to room temperature, water was added up to 250 ml. Then 20 ml of the solution was pipetted into a porcelain dish and evaporated on a water bath. It was heated in an air-oven at 110° C until the weight became constant. After that its yield was calculated (Table 4).

The results show that the portion of total extractives obtained from different-aged trees is more or less the same (8.4-8.6% yield for one extraction). Extractive yield therefore varies directly with wood volume. The older the tree, the higher the yield per unit area of land. Ten-year-old trees are not suitable for extraction due to their low percentage of heartwood and the difficulty in peeling the bark to obtain it. Trees selected for extraction should be older than 10 years old. Selection of trees would also depend on the manufacturing costs determined in a pilot-plant operation.

Determining the Optimum Conditions for Extraction

Laboratory experiments set out to determine the optimum conditions of product extraction, in terms of:

- concentration of the extract
- crystallization, filtration and drying of katha
- preparation of cutch from the filtrate

Table 4. Wood and extractive levels for different-aged trees.

Age	Average girth (cm)	Number of trees /ha*	Wood volume per tree (cm^3)	Wood volume per rai (m^3)	Heartwood (%)	Percentage of total extractives (one extraction)
10	47	481	41,341	3.18	27.1	-***
15	66	219	109,093	3.82	36.1	8.4
20	82	119**	246,252	4.75	41.0	8.6

*Survival of trees planted at 4 x 4 m spacing; **Thinned at 10 years; ***Insufficient for extraction

Toward this end, the experiments set out to standardize the parameters for:

1. Size of chips
2. Chips to water ratio
3. Extraction time
4. Number of extractions from the same batch of chips

Equipment Used

1. Wood chipper
2. Vacuum evaporator
3. Vacuum oven
4. Vacuum
5. Oven
6. Refrigerator
7. Electronic balance
8. Spray dryer
9. Hot plate and gas burner
10. Hydrometer (sp. 1.0-1.2)
11. Beaker
12. Stainless steel extraction pot (capacity 10 *l*)
13. Porcelain basin
14. Funnel and buchner funnel
15. Cotton and filter paper
16. Flask and volumetric flask and pipette

Size of Chips

Extraction is more efficient with thinner chips because of greater water penetration, but very thin shavings occupy more volume in the extractor than an equal weight of thicker chips. The experiment aiming to identify the best compromise thus involved determining the total solids obtainable using a known quantity of water.

Chips of different thicknesses (0.42, 0.48, 0.61, 0.80, 1.01, 1.05, 1.58, 1.84, and 2.19 cm), but of the same length (1.0 cm) and width (1.0 cm), were boiled in 150 ml of water for 2 hours. The water level was marked on the beaker, and the amount lost by evaporation was compensated for by frequent additions of boiling water to keep the water level at 150 ml. While still hot, it was filtered into a volumetric flask of 250 ml capacity and cooled to room temperature. It was once again carefully filled with water to the same mark, and shaken well to obtain uniform concentration. Next, 20 ml of the solution was pipetted into a porcelain dish of known weight. The water in the dish was evaporated completely by heating on a water bath. Then it was heated to a constant weight in an air oven maintained at 110° C and the weight of the dish with the contents was recorded (Table 5).

Table 5. Variation of yield by thickness of chips (80-90°C for 2 hours).

Thickness (cm)	Yield (%)
0.42	5.35
0.48	5.45
0.61	5.27
0.80	4.48
1.01	4.36
1.05	4.28
1.58	3.82
1.84	3.44
2.19	3.64

In this experiment, total solid present in the extract = $(W_2-W_1) \times 250/20$, where W_1 = weight of the empty dish, and W_2 = weight of the dish with residue after evaporation.

The percentage of the extractive that can be obtained under the conditions of the experiment is calculated by the formula:

$$\%\text{of extract} = (W_2 - W_1) \times 250/20 \times 100/W$$

where W = the weight of the moisture free chips, used for the extraction.

Chips to Water Ratio

The greater the quantity of water used, the more material is extracted from the chips. However, the bulk of the extract obtained has to be ultimately concentrated into a solution of the optimum specific gravity required for the crystallization of katha. This would mean wastage of time and energy. The extract normally comes to two to three times the weight of the chips taken for extraction.

This experiment aimed to determine the highest percentage of extractives obtainable from chips using different chips to water ratios. Since extraction can be carried out using just enough water to immerse the chips, a larger chips:water ratio would be justified only if this experiment identified a significant increase in the extractive yield. Extraction was carried out with a known quantity of chips (50 g) of the optimum thickness (0.5 cm, determined by the previous experiment). These were boiled in water for 2 hours using chips:water ratios of 1:1, 1:1.5, 1:2, 1:2.5, 1:3, 1:3.5, 1:4, 1:5, and 1:6. The water level was marked and the water lost due to evaporation was compensated by frequent additions of boiling water to keep the water at the original level. After two hours, it was filtered while still hot into a suitable volumetric flask and the total solid present in the filtrate was estimated (Table 6).

Table 6. Variation of yield by chips/water ratio (80-90°C for 2 hours).

Chips:water (w/v)	Yield (%)
1:1	3.82
1:1.5	3.97
1:2	4.61
1:2.5	4.98
1:3	5.02
1:3.5	5.33
1:4	5.14
1:5	5.40

Extraction Time

With a longer extraction time,more katha and cutch is extracted from the chips. At first, the extraction rate is high, but as time passes the rate decreases to a point at which further extraction is uneconomical. The optimum length of time for extraction was determinedby immersing a known quantity (50 g) of chips of optimum size (0.5 cm) in a beaker with just enough water to cover the chips. The water level was marked, and it was heated to boiling. As in the earlier experiments, the water lost by evaporation was compensated for by frequent addition of boiling water. After varying extraction times (1, 1.5, 2, 2.5, 3, 3.5, 4, and 5 hours), the substance was filtered into a suitable volumetric flask and the total solid present in the filtrate estimated as before. The results were plotted on a graph. Optimum extraction time was considered to be reached when the increase in extractive yield is insignificant compared to the time of extraction (Table 7).

Table 7. Variation of yield by extraction time (80-90°C).

Time (hours)	Yield (%)
1	3.67
1.5	4.77
2	5.10
2.5	5.79
3	5.18
3.5	5.72
4	6.33
5	6.29

Number of Extractions per Batch of Chips

Next, the research aimed to establish how many extractions could efficiently be made from the same batch of chips. The quantity of extractive increases with the volume of water used for the extraction, but more total extractive can be obtained from repeated extractions with a smaller volume of water than from a single extraction with the amount of water equal to the total volume used for the repeated extractions. In other words, extracting 100 g of chips three times (200 ml of water each time) yielded more extractive than a single extraction with 600 ml of water. The yield was greatest from the first extraction and decreased with each subsequent extraction. After a few extractions, the yield becomes uneconomical. The optimum number of extractions from a batch of chips was determined experimentally as follows.

A known quantity (50 g) of chips of optimum size (0.5 cm) was placed in a beaker filled with just enough water to immerse the chips. The water level was maintained as in earlier experiments, and the extraction was continued for the predetermined optimum time. Afterward, the extract was filtered into a volumetric flask and the total solid present in the extract was determined as before.

The chips were then transferred back into the beaker, fresh water was added to immerse the chips, and extraction was repeated and filtrate determined for seven extractions. After the seventh extraction the yield seemed insignificant (Table 8).

Table 8. Variation of yield by times of extraction (80-90°C for 2.5 hours).

Extraction No.	Yield (%)
First	5.49
Second	2.72
Third	1.51
Fourth	0.96
Fifth	0.70
Sixth	0.56
Seventh	0.40

From these experiments, the optimum conditions for extraction appear to be:

1. Chip thickness 0.42-0.61 mm
2. Chips:water ratio 1:2.5
3. Extraction time 2.5 hours
4. Number of extractions 2

Determining Yields of Katha and Cutch

Experiment 1

Extractions were conducted by immersing batches of 1.5 kg of chips in 3.0 *l* of boiling water three times, two hours each time. The combined extract was concentrated in a rotary flask evaporator to a specific gravity of 1.07. It was cooled to room temperature and then kept at 0°C overnight in a refrigerator. The katha, which had crystallized as a light brown solid, was filtered using a buchner funnel and washed with ice-cold water to remove the adhering cutch extract. As much as possible, water was removed from the cake of katha on the buchner funnel by suction and by pressing the cake between sheets of filter paper under a screw press. It was dried at 40°C in a vacuum oven. The color of the katha (yield 3.6%) was as good as that of the sample from the factory in India.

The filtrate obtained was used to prepare cutch. In the first experiment, the filtrate was evaporated from a china dish heated on a boiling water bath to a highly viscous solution which solidified on cooling. The solid obtained was powdered in a grinder. In another experiment, the filtrate was concentrated to 30% and spray-dried using the Spray Dryer of the Department of Chemical Technology, Faculty of Sciences, Chulalongkorn University in Bangkok. The cutch yield was 8.5% based on the weight of heartwood taken.

Experiment 2

The 1,000 g of chips (optimum size 0.5 cm) obtained from a 30-year-old tree in the experiment station in Nakhon Ratchasima were placed in just enough boiling water to immerse them for about 2 hours. The extract was filtered three times, combined, and concentrated to a specific gravity of 1.07 using a rotary evaporator. The concentrated extract was transferred to a beaker or conical flask and cooled to room temperature first, then refrigerated overnight. As before, any katha that had crystallized was and washed three times to remove any adhering cutch solution. After being dried by suction for a time, it was kept at room temperature under shade until it became non-sticky, and then it was moved in a vacuum oven at 40°C. After the weight of the dry katha had become constant, its yield based on weight of wood used for extraction was calculated on a water-bath until it was semi-solid and then cooled to room temperature. The yield was 3.6% katha and 8.5% cutch.

Determining Properties of Katha and Cutch

The 2,000 g of chips obtained from a 20-year-old tree were placed for about 2.5 hours in enough boiling water to immerse the chips. The extract was filtered and the chips were boiled once more in fresh water and then lifted out.

The second filtrate was used to extract the fresh chips (2,000 g). They were extracted once more. Afterwards the extracts were combined and concentrated to a specific gravity of 1.04 using a rotary evaporator, transferred into a flask and cooled to room temperature. The katha crystallized in a refrigerator overnight. Next, the katha was filtered using a buchner funnel and washed with cold water until the solution was clear, and dried in shade.

The filtrate containing cutch obtained after filtering the katha was dried using a water-bath until it was a semi-solid. It was cooled to room temperature and weighed. This experiment yielded 3.3% katha and 8.5% cutch. Both samples were analyzed according to the Indian Standard specifications: IS:2962-1964 (method of sampling and test for katha), IS:3967-1967 (for cutch), and IS:4369-1967 (for katha). From Table 9 it is evident that the catechin content, which is the main criterion for grading katha quality, was as high as 54.42% in the katha sample. Tannin content of the cutch is 63.36% and can be used for tanning leather.

Table 9. Properties of katha and cutch.

Characteristic	Percentage by weight
Katha	
Loss on drying	11.21
Catechin content	54.42
Matter insoluble in rectified spirit	3.05
Insolubes in boiling water	0.34
Water-insoluble solid at room temp. (33°C)	52.66
Total ash	0.23
Acid-insoluble ash	0.01
Cutch	
Tannins	63.36
Non-tannins	27.42
Moisture content	8.20
Total solubles	90.78

Summary

Although the percentage of *A. catechu* heartwood varies with the size of the tree, smaller trees yielded more or less the same percentage of extracts as larger trees. That is to say, the yield from a 30-year-old tree was about 12.1% (3.6% katha + 8.5% cutch) and that from a 20-year-old tree was about 11.8% (3.3% katha + 8.5% cutch). Trees younger than 10 years old are unusable, for the reasons mentioned earlier.

After the experiment, katha samples were sent to the Ganesh Katha Factory in Haldwani, India for an assessment of the product's quality and price. The factory classified the katha quality as fairly good, and offered US$12.60/kg for it (compared to $15.20-15.60 obtained for highest quality). This confirms that further processing of the crude cutch to produce katha and cutch can significantly increase the value of the catechu tree in Thailand.

Factory-scale manufacturing costs of katha in Thailand may differ from those in India due to different production cost factors. These can be assessed only through a pilot plant operation, which could determine the most suitable size and age of catechu trees for factory-scale operations. (Such a pilot project should consider trees over 15 years old at the beginning.)

In view of the catechu tree's abilities to grow well in most soil types, coppice well from a mature stump, and provide various uses from all parts at both a cottage-industry scale and (presumably) at an industrial scale, government agencies should provide technical guidance in utilization and marketing assistance. This would serve to encourage *A. catechu* planting throughout Thailand.

Recommendations

To optimize the value of catechu trees in Thailand, two programs should:

- aim to improve the existing, small-scale local cottage industry, and
- develop a larger-scale cutch industry.

Small-scale Cottage Industry

The indigenous method of cutch extraction should be promoted by:

1. Encouraging rural communities where the raw materials are available to extract crude cutch, thus contributing to their economy through employment and sales of products.

2. Improving the indigenous method in terms of productivity and quality by introducing suitable equipment and skills

3. Encouraging rural communities to plant catechu trees for the cottage industry and (once industrial-scale production is shown to be feasible) as raw material for a larger-scale industry

4. Encouraging villagers to form cooperatives to help them obtain better prices with local traders in the katha and cutch industry, and even deal directly with exporters

In addition to benefitting local economies, such a program might gain for Thailand as a nation substantial foreign exchange from the export of products.

Large-scale Industry

Good-quality catechu products have large potential export markets in the countries of South Asia. Before establishing a large-scale katha and cutch industry, however, it is essential to study the demand, market trends, and the resource situation. These studies might include the following strategy:

1. Assess the type and amount of raw materials needed

2. Assess the demands and trends of catechu products in the international market

3. Study utilization of cutch in the manufacture of tannins, including (a) cutch blending with other tannin materials, (b) cutch refining with oxalic acid, sodium metabisulphite, sodium hydrosulphide, and a mixture of sodium metabisulphite and sodium hydrosulphide

4. Study the potential use of crude catechin presently imported. Its use as coloring and flavoring agent in food and alcoholic beverages has great potential.

5. Investigate the cost-benefit of production and decide the operational parameters for factory-scale production of all products

6. Standardize the optimum conditions for industrial-scale extraction of katha, cutch, and crude catechin

7. Investigate possible collaboration by government and private agencies and industries

Studies 1-4 have been partially conducted by this project, but more detailed work remains, and should be completed by RFD. Along with the results (including the investigation of #7), RFD will prepare a clear proposal for pilot plant studies.

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Discussion Notes

Q: Katha is also produced in Nepal, with 65% smuggled into India. What kind of site does *A. catechu* grow on in Thailand?

A: A variety of sites in different regions, with soils ranging to bare rock and rainfall to low.

B.S. Nadagoudar, from India, confirmed that katha is widely consumed in India, traditionally eaten after lunch and dinner, especially on feast days, at an estimated 10 g per day per person—a huge national demand. It is also used to help quit smoking.

Q: What is done with the chips left over after extraction? In Khon Kaen, perhaps they could be used in the MDF manufacturing plant.

A: They are usually burned as mosquito repellent. Generally little is left over.

Q: The cost and return figures are per extraction. How long does one extraction take in the cottage industry?

A: Three extractions can be done every two days by two persons.

Q: Do these results differ with similar studies in India, for example in terms of tree age?

A: Yes, they differ both for the cottage industry and for yields per tree.

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Acacias in Industrial Development: Experience in Sumatra

C.Y. Wong

Operations on Sumatra

P.T. Indah Kiat Pulp and Paper (IKPP) Corporation's sister companies manage some of the largest pulpwood plantations of *Acacia mangium* in Indonesia, located in the lowland Riau province (0°40' N, 101°36' E), Central Sumatra. A total area of 143,000 ha of plantation, managed over seven years or less, will be developed to meet the pulpwood demand of the company's mill. The present pulp mill uses mixed tropical hardwoods to produce 300,000 air-dried tons of pulp per year. Annual production will rise steeply to 863,0000 air-dried tons per year in 1994. The mill also manufactures quality printing and writing paper, with an annual capacity of 344,000 tons per year.

Climate

The climate in these lowland areas is typically warm and wet, with a mean monthly minimum temperature of 22°C and a maximum of 32°C. The mean annual rainfall is 2,044 mm with 101 rain days. The wettest periods occur between September and December (due to northeasterly tradewinds) and again in April-May (due to southwesterly trade winds). The wettest month is October, with an average of 294 mm rainfall and 12.1 rain days. There is no distinct dry season, although June is usually the driest month, with an average 99 mm rainfall and 5.9 rain days.

Sites

Sites on which IKPP plantations are established vary considerably among three main types: recently clear-felled rain forest, degraded *Imperata cylindrica* grassland, and drained peat swamps. The topographical variation of the area ranges from moderately undulating through terraces to tidal swamp. Flat sites with slope less than 3% often require drainage for plantation establishment, as the water table tends to be high even during drier periods. Elevation in these areas is 2-102 m above sea level. Soil texture ranges from sandy-loam to sandy-clay. Soil pH is generally low (4.0-5.2), particularly in the drained peat swamp, where it is 3.5. Rooting depth is adequate (50 cm or more).

Plantation Development

Pilot trial plantation at IKPP commenced in 1983 with *Acacia mangium, A. auriculiformis, A. crassicarpa, Leucaena leucocephala, Eucalyptus alba, E. camaldulensis, E. deglupta, E. pellita, E. tereticornis, E. grandis, E. urophylla,* and *Paraserianthes falcataria*. By December 1992, a total of 56,096 ha pulp plantations had been established. IKPP has established 49% of its plantations (27,409 ha) on logged-over rain forest sites that were replanted for the mill. The other 51% (28,688 ha) are planted on scrubland and former shifting cultivation areas. Most of these plantations were established in the past four years. The species breakdown and annual planting area appear in Figure 1. Top priority species for plantation establishment are *A. mangium, A. crassicarpa, E. pellita,* and *Gmelina arborea*. The current annual planting target is 25,000 ha to meet the planned expansion of the mill. The first acacia plantings are now mature and have been harvested since late 1992.

Seed Sources

Most of IKPP's older *A. mangium* stands are of Queensland provenances (Cassowary, Jullaten, and Mossman) and Indonesian provenances (Piru, Ceram; Sanga-Sanga, East Kalimantan; Sidei, Irian Jaya; *ex situ* Subanjeriji, South Sumatra). Seed collected from the F_1 and subsequent generations in Subanjeriji are also used for plantations. The growth is variable. There are many spontaneous hybrids of *A. mangium* and *A. auriculiformis* in these older plantations.

Since 1989, good genetic quality seed from Papua New Guinea (PNG), Queensland Cape York, certain other Queensland provenances, Irian Jaya, and Sabah Softwoods seed stands and seedling seed orchards have been used for plantation establishment. Both PNG and Queensland *A. crassicarpa* provenances have been tested in the IKPP plantations.

Nursery Techniques

A centralized nursery using 50-cm^3 plastic root-trainer tubes was constructed to replace the polybag system. It is capable of producing 24-27 million plants per year. An intermittent mist system was installed in the nursery for producing both acacia seedlings and cuttings. The tubes are placed in trays on raised steel production lines. The ridges in the tube encourage the main roots to grow downward; roots are air-pruned at the base of the tube to avoid root coiling.

Establishment Practices

It is IKPP policy to keep 20% of its total forest concession as natural forest reserve (Wong 1992). The policy is to leave a 50-200 m band on either side of the major river systems or ravines to preserve water quality, reduce siltation. and maintain the environment. In the drained peat swamp, the proposed plan is to isolate 400-600 ha of plantation with 50- to 100-m-wide strips of rain forest.

Trees on designated planting areas are felled manually, although some mechanical logging is practiced on flatter terrain. A good burn is essential to kill weed seed and remaining competing vegetation and thus reduce the need to weed later. Burning also improves access for follow-up operations.

On flat or rolling terrain, mechanical cultivation using a V-shaped blade attached to a bulldozer is carried out, mainly on *Imperata* grassland and open scrub land. This operation improves access for planting, reduces weed growth, and stimulates tree growth. On compacted soils of logging tracks, log dumps, and temporary campsites, the soil is ripped, mounded, and fertilized using bulldozers. Vee-blading and ripping are carried out on the contour to reduce erosion and encourage water infiltration.

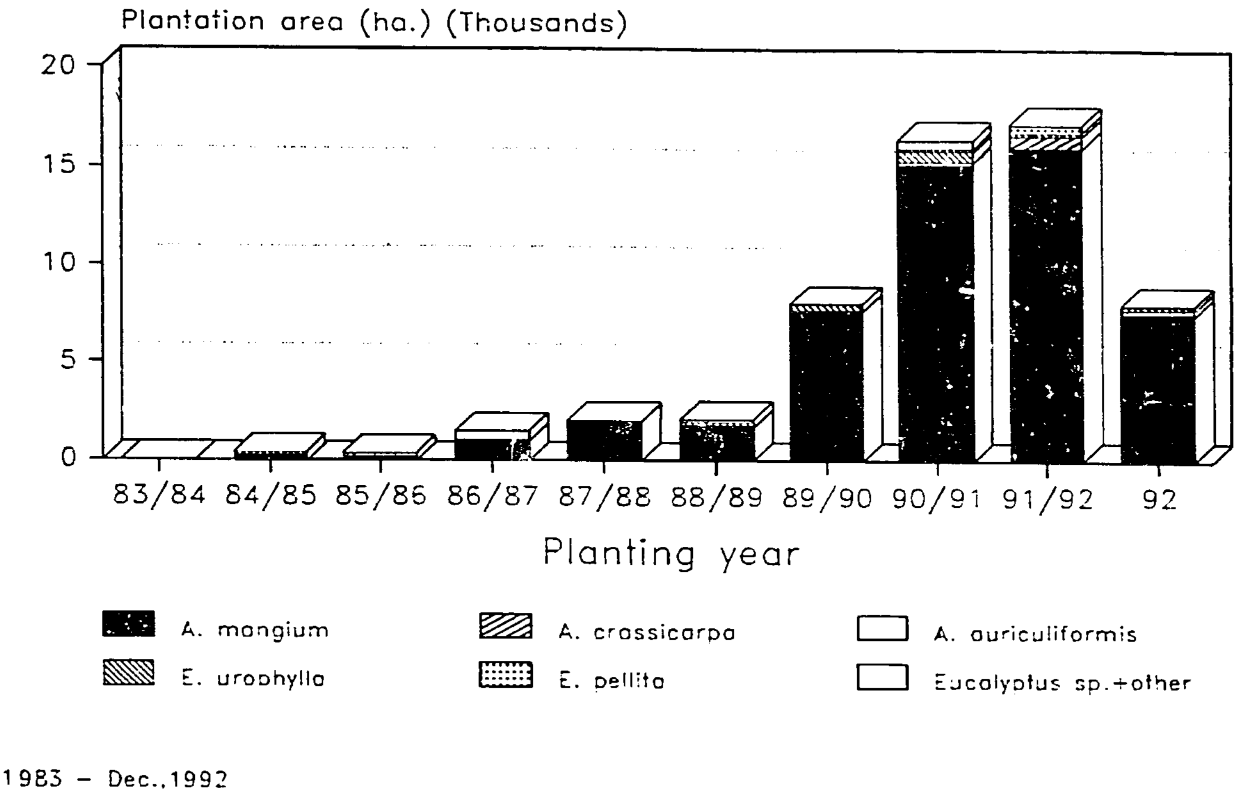

Figure 1. Planting area of PT Indah Kiat Pulp and Paper Corporation, 1983-1992.

Acacias are planted at 2.5 m in-row spacing and 3 m between rows, giving a stocking density of 1,333 trees per ha. On undulating slopes, trees are planted along the contour.

Weeding and Tending

All trees are kept weed-free within the planting circle in the first 12 months. In the ex-rain forest dryland site, one round of circle weeding (by uprooting and circle spraying) is carried out during the first 6 months. Two to three rounds of inter-row hand weedings are carried out in the first 18 months. Noxious weeds are also spot-sprayed with Round-up. Weedier sites such as scrub land and peaty areas require an additional blanket spray. Disc-harrow weeding between the planting rows, followed by hand weeding within the row, is also practiced on flatter sites previously vee-bladed. Except on former rain forest sites, all planting sites are fertilized with phosphate

Acacia trees often produce several stems, especially on a productive site. IKPP's current practice is to single to one leader at 4-6 months of age. The aim of singling is to increase the piece size at harvest. Larger individual trees reduce logging waste and overall harvesting and logging costs. Early singling is cheaper and the wound heals faster.

A no-thinning regime is used on all pulpwood plantations. The planned rotation length is seven years on ex-rain forest sites and 8-10 years on scrub land and former shifting cultivation sites.

Quality Control and Manpower Development

To maintain an efficient and high-yielding forest plantation, IKPP has engaged a quality-control team to check each field operation. A computerized program has also been installed for scheduling and costing each operation. Regular meetings and in-house training programs for field staff provide skills in aspects of forest plantation management. Overseas training for senior staff strengthen their expertise in this area.

Species Performance

Acacia mangium

Growth and Properties

A. mangium has adapted and grown well on a large scale in IKPP pulpwood plantations. It is the least site-demanding species. However, its poor stem form and multiple stems warrant intensive selection and breeding. Multi-stemmed *A. mangium* is largely due to site quality, preparation, and manuring policy rather than genetic control. In a replicated provenance trial, *A. mangium* is grown on ex-rainforest dryland (5,142 stems per ha) and open scrub land (1,198 stems per ha). The trees on the open scrub land are mostly single-stemmed. Both trial sites were mechanically raked, mounded, and manured befo: establishment. There was no significant difference between provenances for number of stems per tree at 6 months of age.

For *A. mangium* at IKPP's plantation, measurement of permanent sample plots indicates a mean annual increment (MAI) of 10-45 m^3 over-bark volume. MAI volume peaks early at 3-4 years, depending on stocking level. In Sabah, where the species is planted on marginal sites, MAI for under-bark volume is 15-27 m^3. In dominant height, the species has an MAI of 2.6-3.3 m and in DBH, 2-3 cm over eight years.

Basic density of *A. mangium* is 420 kg/m^3. Plantation-grown trees have excellent pulping qualities, good bleachability, and high yield. At Kappa number of 21, the screened pulp yield and alkali requirements of 9-year-old *A. mangium* are 52.3% and 14%, respectively (Logan and Balodis 1982). The species' opacity is exceptionally high.

Diseases

Heart rot is common in *A. mangium*, even in stands where singling is not carried out. In seven-year-old stands, the portion of damaged trees ranges from 21-56%, except for one stand where 81% of the trees were affected. In terms of volume losses per tree, damage is negligible (0.7-3%) in the Compensatory Forestry Plantation Project in Peninsular Malaysia (Thang 1992).

Spodoptera sp. and *Euproctis* sp. often defoliate 2- to 12-month-old *A. mangium* stands. Fortunately, the damage occurs in isolated stands and trees recover quickly. Seedlings are also susceptible to a charcoal root disease caused by *Macrophomina* sp. (Ahmad 1985). In isolated stands of plantations three years old or older, a brown root disease caused by *Phellinus noxius* is also found.

A. crassicarpa

Growth and Properties

A. crassicarpa has adapted well to a wide range of soil and pH conditions in Sumatra. On ex-rain forest wetlands where the soil is sandy-loam, the species also shows superior growth compared to *A. mangium* and eucalyptus species. In peaty sites with soil pH of 3.3, it has outgrown *A. mangium* and *E. pellita*. The provenance from Mata, PNG can also tolerate alkaline soils; the Coen provenance from Queensland does less well in West Timor (McKinnell and Setijono 1991). *A. crassicarpa* from PNG has shown significantly better and DBH than Queensland provenances.

Its basic density is 638 kg/m^3 (Clark et al. 1991). At Kappa number of 20.5, pulp yield and alkali requirements of 15-month-old plantation-grown *A. crassicarpa* are 45.4 and 16%, respectively. For *A. crassicarpa* of unknown age growing in natural forest near Kuranda, Queensland, Australia, Clark et al. (1991) reported a screened pulp yield of 47.2% at Kappa number 20.3.

Pests

Ambrosia beetle (*Platypus* sp.) is found on 17-month-old *A. crassicarpa*, although initial incidence of damage is minimal.

A. auriculiformis

Growth and Properties

This species shows tremendous variation in tree vigor and stem form among provenances, with PNG and Queensland provenances substantially taller than seedlots from the Northern Territory and Thailand (Harwood et al. 1991). Among PNG provenances, there is a strong positive correlation between DBH and bole length. Northern Territory provenances also show more multiple stems than Queensland and

PNG provenances. Although *A. auriculiformis* shows slower growth than *A. mangium*, it has some desirable characteristics that could be used to produce F_1 hybrids with *A. mangium* and *A. crassicarpa*.

A. auriculiformis has a basic density of 497 kg/m^3 (Logan and Balodis 1982). At Kappa number of 19.9, pulp yield was 55.0% and alkali requirements were 13% for seven-year-old trees (Logan and Balodis 1982).

Diseases

A gall rust diseases has been found on *A. auriculiformis* leaves in the nursery and in plantation, but the damage is not economically important at this stage.

A. aulacocarpa

Growth and Properties

This species also shows high provenance variation in growth, tree form, and leaf shape, which ranges from oval to lanceolate. In Sumatra, PNG provenances outgrow those from Queensland and the Northern Territory.

The bleached kraft pulp from *A. aulacocarpa* is the strongest of the acacias, followed by *A. crassicarpa* and *A. cincinata*.. Its basic density is 598 kg/m^3. At Kappa number of 19.3, the screened pulp yield is 55.4% for a 12-year-old *A. aulacocarpa* growing in its native forest near Kuranda (Clark et al. 1991). Despite its good pulping characteristics, however, the future potential of this species at IKPP is uncertain.

A. cincinnata

Growth and Properties

Although this species shows good stem form and fine branches, its growth is too slow to warrant serious research at this stage. Its basic density is 580 kg/m^3, and its screened pulp yield at Kappa number of 20.6 is 53.1% for 10-year-old trees growing in native forest near Kuranda (Clark et al. 1991).

Wind Damage

Although wind damage to acacias is generally minimal, *A. mangium* trees are occasionally snapped off or even uprooted. *A. crassicarpa* branches are more friable and susceptible to wind damage, as are many heavily-forked *A.aulacocarpa* trees.

Research and Development

Since 1990, IKPP has conducted forestry research, including a comprehensive series of replicated provenance trials, progeny trials, and clonal tests. Table 1 summarizes the acacias and number of provenances/families/clones included in these trials.

Seed stands and seedling seed orchards have been established to service plantation development. *A. mangium, A. crassicarpa*, and *A. auriculiformis* base subpopulations began in 1989 as the basis for selection of phenotypically superior plus trees for the first generation breeding subpopulation.

With recent advances in vegetative propagation of *A. mangium, A. auriculiformis*, and their hybrid by cuttings (Wong et al. 1991; Haines et al. 1991), IKPP is embarking on an ambitious breeding program for selection and cloning of acacias with desirable growth, tree form, and wood properties. So far, some 4,500 ha of cuttings derived from natural-seed stand

Table 1. Summary of provenance trials, progeny trials, and clonal tests in PT. Indah Kiat plantation companies, 1990-93.

Species	Number of provenances	Number of families	Number of clones
Acacia mangium	43	236	183
A. crassicarpa	14	121	
A. auriculiformis	16	84	42
A. aulacocarpa	18	295	
A. cincinnata	5		
Spontaneous hybrids of *A. mangium* and *A. auriculiformis*			121

seeds of superior provenances have been established. The aim is to produce *A. mangium* trees with MAI volume of 40 m^3/ha on better sites and 25 m^3/ha on marginal sites in the first generation of breeding work, for maximum pulp/ha/year per cost on a sustainable basis. Work has begun in both selection of phenotypically superior plus trees in the base population and controlled pollination.

Conclusion

Although acacias have grown well at the commercial scale compared to eucalypts and other genera, there remains a need for continued research and development in:

- tree improvement (particularly the breeding systems of tropical acacias)
- silviculture
- nutritional studies (including the use of acacias on *Imperata* grasslands as soil conditioners for more-demanding trees species, such as dipterocarps)
- pest and disease control
- harvesting
- transport systems
- utilization research (particularly wood and paper properties)

Additional seed collections in Lake Murray in PNG and Muting in Irian Jaya are warranted to ensure a continuous improvement in productivity and wood quality. A symposium to bring together latest information on species and provenances would be useful, with recommendations forwarded to various international organizations for funding consideration.

Discussion Notes

Q: What is the economic return of plantations on *Imperata* grasslands compared to that of former rain forest sites?

A: Plantations on former grasslands have much lower productivity—10-20 m^3 MAI—and require more intensive weeding and fertilization to establish. For IKPP, however, land area for plantation is scarce, and so the former grasslands are used.

Q: Regarding work with the *A. mangium* x *A. auriculiformis* hybrid: (a) what is its performance in Sumatra, and (b) what other research is planned?

A: The hybrid is very straight and at six months shows improved performance over its parents. As mentioned above, 121 clones have been selected for further research and improvement.

Q: Of the five species grown in Sumatra, what are the relative proportions in planting?

A: *A. mangium* makes up about 70-80% of the plantations, with *A. crassicarpa* after that, and *Eucalyptus pellita* forming about 5%.

Q: You say that the *Imperata* sites are unproductive in the first rotation, but what about once the crown has closed? Is it better?

A: Yes, but lack of topsoil on those sites is also a constraint to growth, even after crown closure.

Q: What is the experience regarding relative performance of cloned plants vs. seedlings?

A: Trials now at 12 months are comparing cutting and seedling performance. Both appear equally good at this stage. Cloning will play a major role in the future at IKPP.

Comment: Still, refinements, such as clonal position, need further work.

Comment: It would be good to know if disc-harrowing damages the root system in any way.

Q: Is there any difference in wood density between trees raised on former *Imperata* grassland and those grown on former forest sites? Any added risk of fire?

A: Differences in wood density have not yet been investigated, as the trees on grassland sites are still young. Regarding fire risk, no serious problems have been experienced so far. The drained peat swamp sites pose a potential problem.

Q: Is *A. mangium*'s multi-stemmed habit affected in cloning?

A: Clones are selected from trees with superior form (as well as vigor and wood quality), so the clones show the same form as the stock material.

Q: Are farmers in the area planting trees as well?

A: The company encourages small farmer-run plantations through agreements by which the company agrees to buy timber produced.

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Recent Developments in Acacia Improvement at Sabah Softwoods

Edward Chia

The theme of this meeting correctly addresses the wide-ranging uses of *Acacia* species. This paper refers to the few acacias commonly grown in the humid tropics: *A. mangium*, *A. auriculiformis*, *A. aulococarpa*, *A. crassicarpa*, and *A. cincinnata*.

One of the outstanding characteristics of these species is their almost unique ability to thrive well on poor and degraded sites (Yap 1986). Their versatile tolerance of poor sites makes them suitable not only as plantation species, but also for socioeconomic and environment conservation projects. In Sabah, social forestry has been incorporated into the reforestation programs of both the Sabah Forest Development Authority (SAFODA)(Shim, pers. comm.) and Sabah Forest Industries (SFI) (Sim, pers. comm.; Nykvist 1993).

As a multipurpose genus, *Acacia* has attracted great interest, especially by industry. As a result of feasibility studies, improvement work is proceeding to enhance these species' performance and productivity, especially for production of chips, pulp and paper. According to analyses by Clark et al. (1991) and Logan (1986), the acacias commonly planted in the tropics are suitable for pulp and paper production. However, acacias—in particular *A. mangium*—have not become primary sawlog species due to their fluty stems and susceptibility to punky knot and heart rot. In Sabah, punky knot—not heart rot—is the more serious problem.

Acacia Improvement Work

Conventionally, acacia planting depends very much on the half-sib family of open pollinated seeds, either from seed stands or seed orchards. Recently, with the increasing demands for acacias as main industrial species, planting efforts have emphasized selected and improved material showing superior growth. The primary aim is to avoid inbred and contaminated material from open pollination plots. There is therefore a need to explore the possibility of establishing clonal plantation through vegetative propagation in order to maintain the quality of improved materials.

Vegetative Propagation

Cuttings

One way to propagate acacias vegetatively is by cuttings. Experiments with acacia cuttings by Sabah Softwoods Sdn. Bhd. (SSSB) started in the early 1980s, but not much progress was achieved until the middle of the decade. Aspects of cuttings studied included: percentage of rooting, nodal position, number of nodes, leaf size, hormonal preferences, number of roots per cutting.

The results showed that successful rooting of cuttings involves the following basic conditions:

- physiologically juvenile cutting material (from a young seedling) or material rejuvenated from coppices of mature trees
- one node per cutting
- use of the third, fourth or fifth node
- leaf size reduced to one-half or one-third of its original size
- application of rooting hormone of Seradix 3 or IBA 2000 (0.2%)

Under these conditions, rooting success with *A. mangium* cuttings is, on average, 70-80% (assuming that the cuttings are placed under the right conditions in the mist propagation chamber); for *A. auriculiformis*, the percentage is even higher. Table 1 shows the results of one rooting experiment studying nodal position using *A. mangium*. In this experiment, cutting material was obtained from *A. mangium* coppices in the field and replicated three times. Each coppice is capable of producing a minimum of seven cuttings. The conditions were as described above. Assessment was carried out after 21 days.

In addition to *A. mangium*, rooting experiments were also carried out on *A. auriculiformis* and the hybrid of these two species. *A. auriculiformis* showed the highest rooting percentage, achieving an average of up to 90% success, followed by the hybrid and *A. mangium*.

Table 1. *A. mangium* rooting percentage at 21 days, for three replications.

Node No.	Replication Number 1	2	3	Average
1	13.3	21.7	66.7	33.9
2	50.0	65.2	90.2	68.5
3	73.3	78.3	84.3	78.6
4	73.3	84.0	70.6	76.0
5	73.3	67.9	76.5	72.6
6	46.7	60.0	65.2	57.3
7	26.7	66.7	68.6	54.0

However, there are some clonal variations. Some clones are more difficult to root than others. Before using a clone for mass propagation, therefore, one should first test its capability to root.

Experiments have assessed the multiplication rates of acacia cuttings from generation to generation for several generations. These experiments studied the number of roots per cutting and rooting percentage per generation, with the aim of providing useful information to forest plantations regarding the number of cuttings needed for the establishment of clonal plantations.

The results indicated that, for *A. mangium*, rooting percentage, root number, and vigor all start to decline after the sixth generation. *A. auriculiformis*, however, can be sustained through the eighth generation without much decrease. The hybrid seems to follow the trend of *A. mangium*.

Other cutting experiments established recently include studies of the field performance of *A. mangium* cuttings:

- on good and poor sites
- from ortets of different heights
- from various nodal positions

These experiments are aimed at obtaining the best planting materials with which to establish a clonal plantation in the future.

Tissue Culture

The other technique for vegetative propagation is the tissue culture method, but this technique is still uncertain for mass propagation of acacias for commercial planting. Generally, materials used in tissue culture are either sexual and asexual. Usually, the sexual method is aimed to perfect the culturing technique by using seeds as the propagation material.

Asexual propagation of acacias is carried out by using selected and improved materials obtained from coppices in the open field. The main constraint experienced by SSSB with asexual propagation is the problem of contamination. This probably results from imperfect sterilization. The common contaminants found in the tissue-cultured samples are budding yeast, filamentous yeast bacteria, *Penicillium* sp., *Nodulisporium* sp., and *Aspergillus* sp. The sterilization technique needs to be improved.

With complications arising from contaminants, production of tissue-cultured plantlets can be quite costly, especially with coppice materials. A good alternative might be to use the cutting method to further propagate valuable materials from tissue culture.

As mentioned earlier, the performance of tissue-cultured materials in commercial forest plantations is still unrefined. So far, the performance of tissue-cultured material in observation plots showed that deformation and stunted growth can occur, for no known reason. Therefore, further study on tissue-culturing techniques and the field performance of planting materials produced by this method is very much needed.

The Acacia Hybrid

The hybrid cross between *A. mangium* and *A. auriculiformis* also shows promising growth. Although naturally-crossed acacia hybrids in Sabah were first noted in the late 1970s (FAO 1982), the hybrid did not receive much study until the late 1980s, when collaborative research began with the Australian Council for International Agricultural Research (ACIAR).

The acacia hybrid possesses a number of attractive characteristics much sought in tree improvement. Generally, it has better growth, straight bole, less persistent branching, and more cylindrical stem (without prominent flute) than its parents. A wood utilitization study showed that the average density of the hybrid is higher than *A. mangium* , but slightly lower than *A. auriculiformis* (Laurila 1992).

The percentage of hybrid from an open-pollinated seedlot can be determined by both isozyme (Wickneswari and Norwati 1992) and seedling morphology identification (Rufelds 1988). An observation plot was established using materials supplied by the Forest Research Institute Malaysia (FRIM) under the ACIAR Project 8630. Instead of discarding the seedlings at the end of the study, they were planted out for observation with two replications in randomized complete block design

Table 2. Average heights (m) of one year old *A. mangium, A. auriculiformis,* and hybrid seedlings.

Rep	*A. mangium*	*A. auriculiformis*	Hybrid (Aa)	Hybrid (Am)
A	3.95	3.33	5.38	4.93
B	3.66	3.25	5.33	5.55
Average	3.81	3.29	5.36	5.24

(Aa) = *A. auriculiformis* mother. (Am) = *A. mangium* mother. SD = 0.895

(RCBD). Each replicate consisted of four species treatments: *A. mangium, A. auriculiformis,* Hybrid (Am), and Hybrid (Aa). In each plot, there were 16 assessment trees.

Table 2 shows the results of the observation plot in terms of average height of one-year-old hybrid seedlings compared with *A. mangium* and *A. auriculiformis.* Obviously, the hybrid trees at this early stage out-performed both parents in terms of height growth.

The Acacia Hybrid as Commercial Planting Material, and Constraints

With its superior growth performance and attractive characteristics, the acacia hybrid is quite promising for adoption by industrial planting programs. However, open-pollinated hybrid seeds are unreliable, as they can be contaminated by undesirable parents if not properly controlled. This is the constraint to producing hybrid seeds for commercial planting.

Therefore, quality hybrid seeds must come from proven parents of superior *A. mangium* and *A. auriculiformis.* This is possible through controlled pollination, especially with the recently developed controlled pollination method (Sedley et al. 1992). However, due to the tiny size of acacia flowers, controlled pollination is a tedious and impractical exercise. Therefore the most reliable means of mass propagation for producing true-to-type planting material is probably vegetative propagation of cuttings, or alternatively establishment of a bi-clonal orchard.

Bi-clonal Orchards

In order to produce a sufficient amount of naturally crossed hybrid seeds for large-scale planting, bi-clonal orchards must be established, using selected and improved *A. mangium* and *A. auriculiformis* at isolated sites to avoid contamination.

Recently, seeds from synchronously flowering branches of both parents were harvested from bi-clonal orchards. Seeds harvested from each parent were kept separate. To assess the hybrid percentage, the seeds were sown in five replications with 100 seeds each. Hybrid seedlings were assessed using Rufelds' method. Seedling morphological identification revealed that when hybridization occurred with *A. mangium* as mother, seedlings would have the mother's characteristics. The preliminary results (Table 3) showed great variation in terms of hybrid percentage, which conflicts with the properties of acacias as outcrossing species.

Hybridization did not occur on *A. auriculiformis* in bi-clonal orchards B and C, and *A. mangium* in bi-clonal orchards F and H, but the reasons for this are unclear. These are only preliminary results; further monitoring of the hybrid percentage for several more seasons will be needed before any conclusions can be drawn.

Table 3. Percentage of hybrid seed found in SSSB's bi-clonal orchards.

Orchard	Hybrid %
B	1.7 (Am)
C	2.28 (Am)
F	64.31 (Aa)
H	6.56 (Aa)

Probably the unsynchronized flowering pattern of *A. mangium* and *A. auriculiformis* poses the main constraint in the production of natural hybridized seeds. Normally, *A. mangium* flowers earlier than *A. auriculiformis*. In most cases, the overlapping period (if any) is not until the end of *A. mangium*'s flowering season.

Therefore before matching both the two parents (Am x Aa) in the bi-clonal orchard, it is important to study the flowering pattern of both parents to ensure optimum synchronous flowering. A detailed phenology study of both parents is crucial before establishment of bi-clonal orchards.

Controlled Pollination

Although controlled pollination work with *A. mangium* and *A. auriculiformis* can be very tedious, its importance cannot be overlooked. Despite the fact that controlled pollination may not be a feasible method for producing large quantities of seeds, it can be used to produce specific hybrids for further testing and eventual large-scale planting through vegetative propagation.

Besides being tedious, controlled pollination of acacias poses the constraint in storage of pollen. This is due to the variation in the flowering patterns of both species. Without a good knowledge of pollen storage, production of manipulated hybrids will remain limited.

Concluding Remarks

Improvement works on acacias in recent years have made these species popular for both social and industrial purposes. Techniques developed for vegetative propagation (by cuttings and tissue culture), hybrid verification (isozyme analysis and seedling morphology identification), and controlled pollination have contributed greatly to the increased use of the genus.

Generally, most acacia work has focussed on *A. mangium*, *A. auriculiformis*, and their hybrid. It is high time for further studies on *A. crassicarpa* and *A. aulococarpa*, which are known to be even more site-tolerant (Sim and Gan 1991). *A. cincinnata* also merits more studies, as its growth has been found to be better than *A. auriculiformis* (Anuar 1986).

Assessment of the field performance by materials produced from cuttings and tissue culture is essential, as it will provide a useful guide for establishment of clonal plantations. To date, no large-scale acacia clonal plantations have been established by either cuttings or tissue culture.

Extra effort should be devoted to biclonal orchards, particularly on the phenological aspects of *A. mangium* and *A. auriculiformis*. Perhaps the plants can be manipulated to optimize synchronous flowering of the two parents. For controlled pollination, studies should focus on pollen-handling techniques in order to facilitate production of specific hybrids.

Discussion Notes

Q: Partial self-incompatibility has been detected in both *A. mangium* and *A. auriculiformis*. Has this been used to advance hybrid seed orchards?

Comment: From Table 3, it appears that the best percentage of hybrids obtainable was only 64%, which is not very good. More self-incompatible individuals need to be found before this can be used effectively, and the search is complicated by the need to select for economically desirable traits.

A: It is true that self-incompatibility should be a factor in selection, not merely compatibility with the other parent species. Regarding controlled pollination, sometimes the pod forms without seeds; controlled pollination can introduce a fungus that causes the pod to abort.

Isozyme studies of natural populations have shown outcrossing rates of 85-90%, but in plantations where a narrower gene pool is available, the species seem to be able to self more readily. This requires more research that may not be feasible for private companies to undertake.

Q: Within two years from establishment, *A. mangium* can seed heavily for use in propagation, without the risks imposed by the narrower genetic base involved in clonal production. What, then, is the significant advantage of clonal propagation over seeds?

A: Greater control of standing crop characteristics. Also, with continual infusion of other provenances as they are collected, clones can continue to be improved without further narrowing the genetic base.

Q: What potential do you see for use of *A. mangium* as saw logs?

A: New technologies using fingerjoints may get around the problem of punky knots. Again, in Sabah the main commercial production objective is chips, so heart rot is not a problem.

Comment: Regarding saw logs, *A. aulacocarpa* in natural stands is valued for saw logs in Australia—it is more or less exchangeable with *A. melanoxylon*, one of Australia's most valuable saw timbers.

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Acacias for Non-wood Products and Uses

Hsu-Ho Chung

Introduction

In recent years there has emerged a genuine, world-wide concern for the well-being of tropical forests and the forest-dwelling communities who derive their livelihood there. This concern has provided a driving force for the integration of non-wood products/uses (NWPU) as a component in sustainable, multipurpose forest systems that enhance rural welfare as well as the ecosystem's structure and functions. Much information exists on NWPU, but most of it is based on observations of traditional production/uses and is highly diffuse. Technical information based on well-designed studies are scarce; this is particularly true of acacias. It is therefore difficult to give an account of NWPU from acacias, but this paper will attempt to do so briefly.

Non-Wood Products/Uses Defined

In this paper, 'non-wood products/uses' is defined as all renewable and tangible biological materials (other than industrial roundwood and derived sawn timber, wood chips, and wood-based pulp) that can be extracted from forests (either natural stands, managed plantations, or otherwise) and utilized in the household, marketed, or have social or cultural significance (Wickens 1991). NWPU thus includes extractive products (gums, resins, latex, tans and dyes, essential oils), medicines, plant food products, fiber products, fodder, and animal and animal products other than food (Rao 1991). The present definition also includes charcoal and firewood, but will not be treated here as this subject is covered elsewhere in this volume (see the paper by Yantasath et al.).

"Service" functions (amenity value, conservation functions, etc.) are not considered as NWPU here. Except for bee honey, animal products (see Rao 1991) are also excluded since in most cases their production is not relevant to acacias.

Existing and Potential NWPU of Acacias

There are over 1,000 *Acacia* species worldwide; in Australia alone, over 900 acacias have been recorded (Booth 1987). Each acacia undoubtedly has some existing and/or potential uses as NWPU, and so to prioritize a list of acacias for NWPU is difficult. This paper will focus on the 12 priority species identified for silvicultural and utilization research in the Asia-Pacific region at the first meeting of the Consultative Group for Research and Development of Acacias in 1992 (Awang and Taylor 1992). Table 1 is a summary of the existing and potential NWPU of these 12 acacias, based on a personal effort at an exhaustive literature search; however, certainly much information is missing from it.

Similar tables using different approaches and formats were prepared

Table 1. Summary of reported non-wood products/uses of priority acacias identified at COGREDA's first meeting.

Species	Product/Use	Comments/Relevant Reference
Humid/Subhumid Species		
A. mangium	Bee honey	Commercial-scale production studies recommended (Hanover 1988). See also the papers by Nadagoudar and Zheng and Yang in this volume.
	Adhesive	Marketing studies recommended (Mohd. Nor. et. al. 1988).
	Fodder	Further evaluation warranted (Vercoe 1986, 1988).
A. auriculiformis	Craft (Dye)	Further technical studies warranted (Hanover 1988).
	Gum, Protein/tannin	Further technical studies warranted (Abdul Razak et. al. 1981).
	Fodder	See *A. mangium*.
A. aulacocarpa	Fodder	Further studies not suggested; digestability <40% (Vercoe 1986).
	Other NWPU	Information not available.
A. crassicarpa		Information not available.
A. leptocarpa	Fodder	Further evaluation warranted (Vercoe 1986, 1988).
	Other NWPU	Information not available.
A. oraria	Fodder	Not known to have fodder value (Turnbull et. al. 1986).
	Other NWPU	Information not available.
A. cincinnata		Information not available.
A. confusa	Medicine	Leaf extracts, minor importance (Kan 1977).
	Other NWPU	Information not available.
Semi-arid Species		
A. nilotica/	Tannin	Extracted from both bark and pods; produced at commercial scale.
*A. arabica**	Gum arabic	Commercially valuable.
	Fodder	Has potential; recommended for further evaluation.
	Medicine	Bark extracts can have medicinal uses; further studies suggested.
	Molluscides/ algicides/fungicides	Have been proven effective; recommended for further evaluation (For all three of these see Fagg and Greaves 1990).
	Honey	Further evaluation recommended (Hanover 1988).
A. catechu	Medicine	Katha is commercially produced (Hanover 1988).
	Dye	Black cutch. See Subsansenee et al. in this proceedings.
	Food coloring agent.	Further technical studies warranted (Kamik et al. 1973).
	Honey	Recommended for further evaluation (Mishra and Kumar 1987).
A. pennata		Information not available.

*In most literature on non-wood products/uses, *A. nilotica* and *A. arabica* are synonyms.

by Hanover (1988) and Rao (1991). Table 1 differs greatly from those in that those papers present species already either well-known for non-wood products or at least for having proven potential in that regard; on the other hand, the primary uses of most species in Table 1 are wood-oriented. While NWPU of *A. nilotica* (syn. *arabica*) for gum arabic/tannin and of *A. catechu* for katha/tannin production are well documented, such information is simply not available (or to a very limited extent) for other acacias. This suggests needs and opportunities for further research.

Other than bee honey, Table 1 does not cite acacias for food production. This topic is well covered in a recent proceedings (House and Harwood 1992). None of the Australian acacias in Table 1 were mentioned in that proceedings as promising for human food because they are more humid/subhumid species. However, a high-value plant food product, shiitake (*Lentinus edodes*) has been successfully cultivated from *A. mangium* for commercial-scale production (Huang et al. 1988). Another edible mushroom, *Tylopilus felleus*, is common in plantations of *A. auriculiformis* in Thailand (Pinyopusarerk 1990).

Finally, except for some potential uses as dye, Table 1 does not mention acacias for craft use. There is no question that acacias may have a limited potential as handicraft material for development in local industries. Handicraft products of *A. confusa*, for example, have been produced in Taiwan, but they do not appear to appeal to either tourists or overseas ethnic markets due, to a great extent, to the poor quality and color of the wood (researchers at Taiwan Handicraft Research Center, personal interviews).

Prospects

In general, many of the research needs and prospects identified by Hanover (1988), De Beer and McDermott (1989), FAO (1991), and Rao (1991) apply to most forest plants, including acacias, for NWPU. The following are some specific (and perhaps highly biased) observations with respect to acacias in Asia-Pacific.

1. Research should set out to fill the information gaps identified in Table 1.

2. Research and development (R&D) should be participatory, with active involvement of farmers, forest managers, and others who will be implementing the research findings. This is of critical importance in sometimes conservative rural communities, in order to guarantee that research findings will be consistent with the rural end users' needs and preferences and thus adoptable.

In Taiwan, for example, researchers developed the use of leaf biomass from a *Cinnamomum* sp. as mushroom substrate, but farmers were reluctant to plant the species. TFRI persuaded the Taiwan Sugar Co. to establish the new variety on its large wasteland areas as a demonstration for farmers. This demonstration convinced farmers of the tree's value; however, acceptance would be much faster if farmers were involved from the start (for an example of concurrent assessment of species growth performance and product acceptability, see Rakouth 1991).

3. R&D programs should be tailored according to various options, depending on the situation:

NWPU improvement vs. development: Since in most cases, the production and utilization of NWPU are traditional and highly localized, research is often needed to evaluate the existing local technology in view of recent technological developments for quantitative and qualitative improvement. A similarly broad comparative approach should also be applied in developing new NWPU particularly in the case of value-added, highly marketable ones.

NWPU research for small farmers vs. research for large industries: Where small farmers are the end users of the findings, NWPU research should aim to improve farmers' income through production of the highest marketable value of NWPU from their limited farm land. This may entail breeding for several options (i.e., several varieties for different primary end uses), rather than breeding one variety for all uses. Feasibility studies should focus on establishing small, local enterprises and/or NWPU processing centers. Furthermore, studies should assess policy effects and the role of non-government organizations (NGOs) in safeguarding farmers' interests in marketing their produce.

Research for large industries should emphasize improvement of quantitative production and processing efficiency of NWPU, particularly if these are considered "by-products" of other (for example, wood-based) management operations.

NWPU research on man-made forest systems vs. research on natural forests: The former aims for optimum production/uses through intensive management of plantations, farm forest operations, homegarden, etc. It should therefore be more process-oriented to produce high-qualities and/or quantities of NWPU, and be market-oriented.

On the other hand, NWPU research in natural forest systems should consider sustaining and enriching resources of useful/potential acacias so that local forest communities do not suffer from their shortage, particularly in times of hardship such as famine. For example, in Papua New Guinea, loggers leave *Terminalia* sp. standing to provide continued fruit harvests for local inhabitants.

Future research vs. research for the future: Many of the 'future research needs' identified and proposed for NWPU deal with improvement of their existing production/uses (see 3.1. above). The paper by Subsansenee et al. in this proceedings provides an example of a systematic approach for this.

With the rapid socioeconomic change in the Asia region (particularly in humid/sub-humid areas), managers of R&D programs for NWPU should recognize such social and technological transition and adjust the path of their program accordingly to produce the NWPU that will be needed by a rapidly changing society. R&D projects for some traditional NWPU may have to be phased out as consumer habits change or products are substituted; and new NWPU for which there will be societal demand in the future should be anticipated and developed.

In other words, research project managers should consider (perhaps several) future scenarios of product use and needs. For example, in Taiwan, *A. confusa* was studied in the 1940-50s for use as charcoal; 15-18 years ago, however, Taiwan started using natural gas, on which it is now completely dependent. The 20,000 ha of *A. confusa* now stand useless, unmanaged, and a fire hazard. Anticipation of changes in energy technology and in Taiwan's role as market/producer might have prevented this.

Discussion Notes

As a mushroom grower, Dr. Chung sees a future in mushroom production for domestic and export using *A. mangium*. Currently farmers in ROC harvest US$15,600 per ha from 7-year-old *A. mangium* plantations.

Q: Are fast-growing species more suitable for mushroom cultivation than longer-rotation trees? On what basis?

A: The ideal remains slow-growing trees in the family Fagaceae, but for faster returns, acacias are suitable.

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Innovations in the Utilization of Small-Diameter Trees, Particularly Acacias

Razali Abdul Kader

Introduction

Acacia mangium is widely planted commercially in Southeast Asia; in fact, it could well be the major source of general utility timber and fiber for paper and engineered panel products in future. Other acacias are also being tested in plantations.

Utilization of plantation timber species needs to be well planned and, above all, efficient, because they are different from the indigenous woods from natural forests around which processing and conversion machineries and technologies have evolved. Plantation species are available in large volume and have small diameters and a high percentage of knots and juvenile wood. Despite these characteristics, they can still be converted into conventional products such as lumber, panels, pulp, and paper to satisfy consumer demand. Table 1 summarizes the use of wood elements in diminishing dimensions. This paper focuses on the potential uses of small-sized acacias in the forms of solid wood and composites.

Solid Wood Products

State-of-the-art processing machinery with relevant supporting devices and their operations are available for converting small-diameter (30 cm and less) logs into lumber with good economic returns (Razali 1992). With attention to equipment and its operations, Risbrudt and Kaiser (1981) obtained a further 3% increase in lumber recovery with two to three times greater value due to increased volume and more clear boards recovered from each log.

In addition, the SDR (saw, dry and rip) method of live-sawing used in North America for small-size logs has also been used with rubberwood (*Hevea brasiliensis*) in this region. The SDR technique combines the attributes of sawing geometry and drying technique to solve the problem of warp in young woods. This technique of lumber conversion should also be tested with acacias; Tong (1990) provides a detailed description.

Laminated veneer lumber (LVL), an engineered product, is another important solid wood product with potential as high-quality structural building material Advances in veneer peeling technology have made it possible to extract more veneer for conversion into LVL from small-diameter trees. LVL from *A. mangium* with all plies and grain parallel to the length is being tested. Salim (1992), Sasaki et al.(1990) and Wang et al. (1990) have shown that it can meet the mechanical requirements of the Japan Agricultural Standard for LVL.

Although plantation stock shows a high incidence of knots, which reduce the potential for structural applications, engineered panels such as LVL could be used as lumber to increase the wood's value. This is possible because the knots,

Table 1. The wood elements in a series of diminishing dimensions. Figures indicate inches; figures in parentheses indicate mm.

Element	Length	Width	Thickness	Glued Products
Lumber	48-240 (1,000-6,000)	4-12 (100-300)	0.5-12 (10-300)	Beams and arches
Veneer	48-72 (1,000-2,500)	4-48 (100-1,200)	0.02-0.5 (0.5-10)	Plywood and laminated veneer lumber (LVL)
Wafers	1-3 (25-75)	1-3 (25-75)	0.025-0.05 (0.5-1)	Waferboard
Flakes	0.5-3 (10-75)	0.5-3 (10-75)	0.010-0.025 (0.25-0.6)	Flakeboard
Strands	0.5-3 (10-75)	0.25-3 (5-75)	0.010-0.025 (0.25-0.6)	Oriented strandboard
Splinters	0.5-3 (10-75)	0.005-0.025 (0.15-0.6)	0.005-0.025 (0.15-0.6)	Splinterboard
Particles	0.05-0.5 (1-10)	0.005-0.25 (0.15-1)	0.005-0.025 (0.15-0.6)	Particleboard
Fiber-bundles	0.05-0.5 (1-10)	0.001-0.010 (0.03-0.3)	0.001-0.010 (0.03-0.3)	Fiberboard
Fiber fibrils	0.02-0.5 (0.5-10)	0.00001-0.001 (0.0003-0.03)	0.00001-0.001 (0.0003-0.03)	Paper
Cellulose/ lignin		Molecular dimensions		Plastics, films, filaments

Source: Marra (1983)

splits, checks, and other natural strength-reducing defects are cut out or are dispersed throughout the panels. Figure 1 illustrates some of the uses of LVL, by itself and in combination with other wood products.

The value of lumber produced from acacias can be increased further by simple processing into moldings. Short materials are finger-jointed, molded, and veneer-wrapped as necessary. Otherwise, these moldings are painted to suit buyer preference. LVL can also be molded and laminated for specific needs. In 1986, the export of wood moldings by the ASEAN member countries amounted to US$258 million FOB, and in 1990 the figure rose to US$460 million, indicating the market's readiness to accept more moldings.

Particle/Fiber-based Wood Panels

Thinnings from acacia plantations and logs not suitable for lumber conversion can be processed into various board products. Some are manufactured for structural applications, others are not. Builders today have access to a variety of new structural and non-structural building materials. It is therefore up to the manufacturers to produce consistently quality panel products that are performance oriented, i.e., designed to meet specific needs. Razali (1992) has earlier proposed the manufacture of some of these products, such as particleboard and medium density fiberboard (MDF) from *A. mangium*. It is technically feasible to manufacture such boards by processing the wood into particles or fibers/fiber bundles and bond them well with existing commercial resin adhesives; this would not require much production line modification. The boards could be overlaid with wood veneer, paper, or plastic overlays to provide desirable faces in case the natural dark color of acacia wood is not preferred by the market.

Other high-value panel products are waferboard and oriented strand board (OSB). Waferboard is a structural board made of wood wafers that are cut to predetermined dimensions, randomly distributed and bonded with phenolic resin adhesive. OSB is made of flakes or strands that are narrower than those generally prepared for waferboard. The resin coated strands are hot-pressed into three-layer panels composed entirely of oriented strand layers (although the core may sometimes be random) purposely aligned in the machine direction. This makes the panels stronger, stiffer, and improves their dimensional properties.

Such panels are intended for use as sheathing and/or for combination subfloor/underlayer, depending on the thickness. The panels are subjected to bending stress and concentrated static and impact loads. Further, they should also provide racking resistance to the floor. There is continuing strong demand for these structural board products; the raw material supplies are changing, and traditional panels like softwood plywood are getting more expensive.

Composites of Wood/Fiber and Non-wood Materials

Acacias and other small-diameter trees can also be processed into composite products in combination with plastics, besides the conventional wood-fiber/particle (sandwich) composites. The technology for combining these two materials is

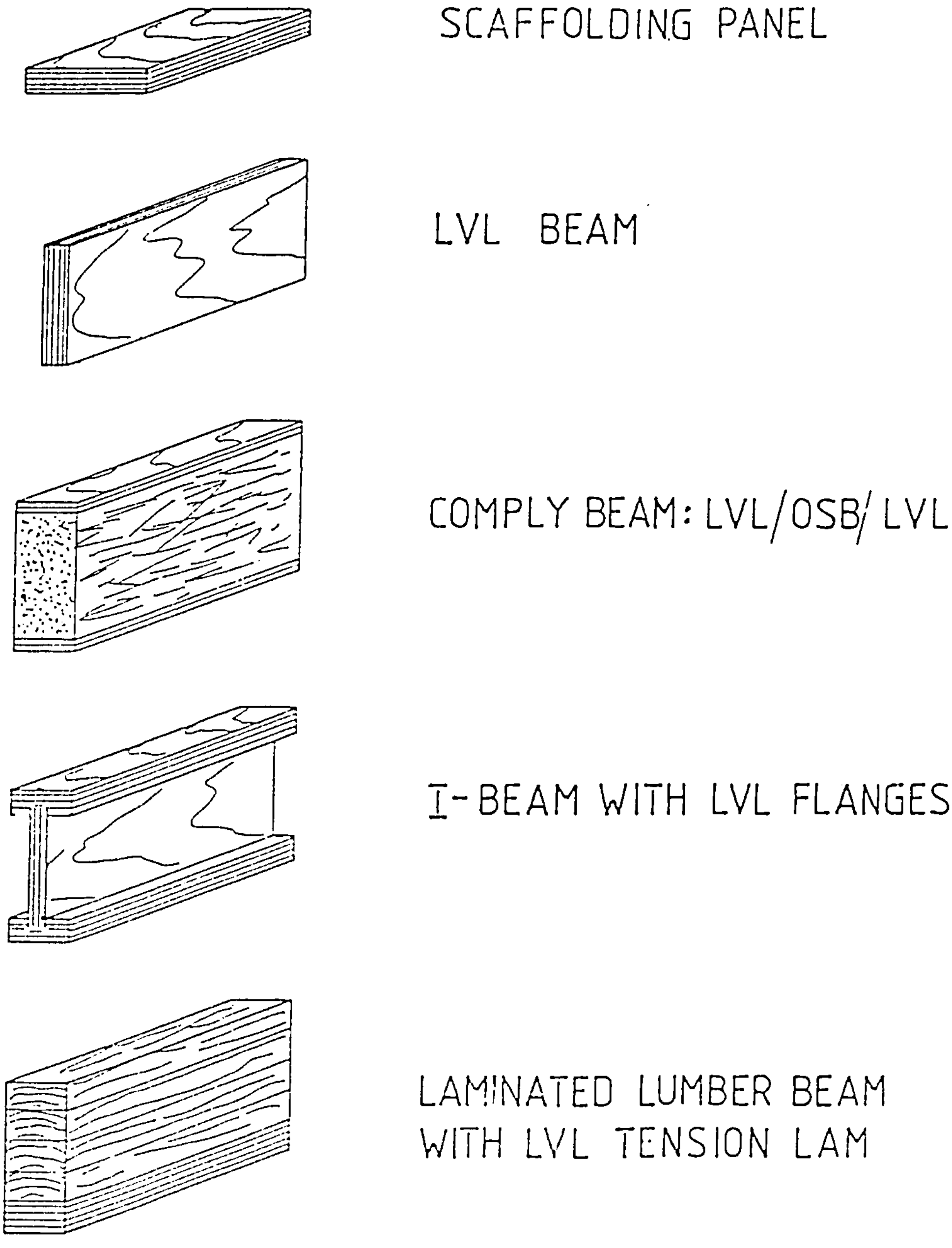

Figure 1. Uses of laminated veneer lumber (LVL).

continually evolving. The wood is first reduced to particles, fibers, or fiber bundles and then put back together into panels of desired dimensions by a special manufacturing process. The end products have the advantage of having properties of both wood and plastic: improved acoustic, impact, and heat reformability properties.

Youngquist et al. (1992) noted that wood and synthetic fibers can be assembled into a web or mat using air-formed, non-woven web technology. The fibers, which are initially interlocked mechanically, are thermoformed into panels or various molded products. Additional bonding can be achieved by incorporating thermosetting resin in the web. Earlier work by Youngquist et al. (1990) and Razali et al. (1992) resulted in boards with varying mechanical properties meeting various MDF grades, depending on the wood to plastic ratio used. The common synthetic fibers used are polyester, polypropylene, and polyethylene terephthalate (PET). The development of this technology is timely, as the conjugate MDF can be molded to produce automobile interior components.

Low-grade acacia wood, particles, or fibers can also be acetylated with the right catalysts and conditions to make products more dimensionally stable and resistant to micro-organisms and termites without losing much mechanical strength. Detailed processes for tailoring these materials to specific end uses have been discussed by Imamura et al. (1986 and 1989) and Shiraishi and Yoshimi (1992).

Conclusion

Small-diameter acacias can be converted into general-utility products, or tailored for specific end uses. Technologies are available to transform them into high-value engineering materials. Their wood requires low processing energy input (and so is economical to process and use), is strong, and above all is renewable and available. However, to ensure product quality, wood properties need to be controlled through proper grading, treatment, or reconstitution. The market-driven product development approach should be adopted for introducing "new" raw materials like acacias into the marketplace.

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Acacias for Environmental Conservation

Reynaldo E. Dela Cruz

Introduction

The area of natural forests worldwide had been decreasing at an alarming rate following an increase in the human population, which has exerted tremendous pressures on the natural forests. Over the past 50 years, economic activity and the rate of population growth has increased to the point at which the effects of human activities on the environment can no longer be ignored. The quality of many of the basic elements of the natural resource base—including air, water, and soil — is deteriorating (Lupo and Brown 1980).

Among the major roles played by natural forests in environmental conservation are:

- conservation of carbon dioxide (CO_2)
- conservation of soil
- conservation of water
- nutrient storage and release
- conservation of soil micro- and macrofauna
- microclimate amelioration

The first of these has global implications, while the rest are important at the national or microsite levels. This paper explores whether *Acacia* plantations can also fill these roles in environmental conservation.

Conservation of Carbon Dioxide

Forests are a major sink for carbon and fill an important role in the global carbon cycle (Schroeder 1992). Not only do forests contain huge amounts of carbon, they exchange it very actively with the atmosphere. On average, the equivalent of the entire CO_2 content of the atmosphere passes through the earth's terrestrial vegetation every 7 years, and about 70% of the entire exchange occurs through forest ecosystems (Waring and Schlesinger 1985).

Due to the activity of this exchange, forest area expansion may therefore present an opportunity to increase the terrestrial carbon sink and slow the increase in atmospheric CO_2 concentration. The tropical zones of the world appear attractive for forestation due to the high productivity rates that can potentially be attained there, favorable weather and rainfall patterns, and the availability of large areas that could benefit from tree planting. Many studies on forestation potentials suggest that the tropics may offer a good opportunity to fix and store large amounts of carbon, and thereby reduce the area required to store a given amount of carbon (Marland 1988; Schroeder and Ladd 1991). Marland (1988) computed that the area required to capture annual carbon emissions from fossil fuel combustion worldwide could be reduced by 25% if forestation efforts were centered in the tropics. Grainger (1988) estimated that the tropics contained over 2 billion ha of depleted or degraded land, of which 758 million ha were once forested and could theoretically be reforested.

The dilemma is that many tropical plantation species (including acacias) are relatively short-lived, and are grown on rotations of less than 20 years. When a stand is cut, much or perhaps all of its carbon returns to the atmosphere within a short time. Schroeder (1992) calculated the carbon storage potential of short-rotation tropical tree plantations. Table 1 summarizes the estimated yield and mean carbon storage of several tree species, among other parameters. *Acacia mearnsii* shows the highest carbon storage potential of 78 tons C/ha on a 10-year rotation. On the other hand, *Acacia nilotica* was estimated to have a mean carbon storage potential of 17 tons C/ha on moderate sites and only 12 tons C/ha on degraded sites.

Table 1. Yield, rotation, wood density, and carbon storage potential for nine plantation species.

Species	Final yield (m^3/ha)	Rotation length (years)	Mean annual growth (m^3/ha/year)	Wood density (g/cm^3)	Mean C storage (t C/ha)
Pinus caribaea	300	15	20	0.46	59
Leucaena spp.					
poor site	72	8	9	0.60	21
fuelwood crop	140	7	20	0.60	42
Casuarina spp.					
moderate site	140	10	14	0.83	55
degraded site	50	10	5	0.83	21
Pinus patula	400	20	20	0.45	72
Cupressus lusitanica	340	20	17	0.43	57
Acacia mearnsii	250	10	25	0.60	78
Cassia siamea	100	10	10	0.58	28
A. nilotica					
moderate site	60	10	6	0.60	17
degraded site	45	15	3	0.60	12
Azadirachta indica	40	8	5	0.52	8

Adapted from Schroeder (1991)

Soil Conservation

Soil Property Changes after Removal of Natural Forests

The effects of deforestation on soil properties in natural forests can be determined by comparing soils under a natural dipterocarp forest and an adjacent grassland, as done by Ohta (1990a), who compared soils under a natural dipterocarp forest and a grassland in the Philippines in terms of morphology, clay mineralogy, physicochemical properties, nitrogen fertility, and humus composition. It should be stressed that the grassland soil was once covered with natural dipterocarps and had been degraded by slash and burn agriculture, overgrazing, and other human activities.

Soil Morphology

Table 2 summarizes the morphological characteristics of the two soils. While horizon patterns were basically similar irrespective of vegetation type, structural development in the surface horizons was greater in the forest soils than in the grassland soils. This may be due to greater soil fauna activity due to higher development of the tree root systems in the forest. Organic horizons were formed on the surface while no organic horizon was present in the grassland soil. In the upper horizons under the forest soil, the presence of many mycelia, mycorrhizae, worm casts, and animal burrows indicated a high activity of soil fauna; no such activities were found in the grassland soil. The influence of land degradation on soil morphology was most conspicuous for soil fauna activity.

Grassland soils were characterized by extensive crack formation in the Bt horizons, not found in the forest soils. This was probably due to the more pronounced drying of soils under grassland than under forest cover, particularly in the dry season.

Soil Physical Properties

Table 3 shows some physical properties at different depths. Bulk density, which was lowest for the surface soil (0-5 cm), increased with depth up to the 25-30 cm layer. The upper layer of the forest soils displayed a distinctly lower bulk density than the corresponding grassland soil, although no significant differences in the values in the deeper layers were detected.

The pattern of the total pore space percentage was the reverse of that of the bulk density: fine pore space percentage was higher in the forest soils than in the grassland soils at depths 0-5 and 5-10 cm in both plots. For the forest soils, the highest percentage of fine pores was observed in the 5-10 cm layer, while the values tended to be highest in the deeper 25-30 cm (GL-2) or 65-70 cm (GL-1) layers for the grassland soils. This difference may be attributed to the more extensive crack formation in the grassland soils.

Hydraulic conductivity was higher for the forest soil than for the grassland soil in the 0-5 and 5-10 cm layers (plot 1) or in the 0-5 cm layer (plot 2). There was no significant difference between the two soil types in the deeper layers. The soil moisture content of the fresh samples collected in the dry season was extremely low in the grassland soils compared to that in the forest soils at the depths of 0-5 and 5-10 cm. This difference reflected the more pronounced drying of the surface soil in the grassland than in the forest during the dry season.

Table 2. Morphological characteristics of a forest and adjacent grassland soils in Carranglan, Nueva Ecija, Philippines.

Soil	Horizon	Depth (cm)	Color (moist)	Structure	Other notable features
Forest (NF-1)	O_1 (L)	4-0	-	-	
	O_2 (F)	very thin	-	-	
	A	0-5	7.5YR 2/2	Strong medium blocky; moderate fine granular; weak very fine crumb	Many coarse (5-10 cm) worm cast aggregates on soil surface; many mycelia; many mycorrhizae
	E	5-15	7.5YR 2/2.5	Moderate medium and coarse subangular blocky	Common mycelia
	Bt1	13-29	7.5YR 3/3.5	Moderate medium and coarse angular blocky	Few mycelia; broken thin cutans; many burrows of soil animals
	Bt2	29-51	7.5YR 3/4	Weak, medium and coarse angular blocky	Continuous moderately thick cutans
	Bt3	51-71	7.5YR 3/4	Very weak coarse angular blocky	Broken thin cutans
	Btg	71-100+	7.5YR 3.5/4	Very weak coarse angular blocky	Broken thin cutans
Grass-land (GL-1)	O	-	-	-	
	A	0-5	7.5YR 2/2	Moderate fine, medium, and coarse subangular blocky; moderate very fine and fine angular	
	E	5-15	7.5YR 2/2.5	Strong, medium and coarse subangular blocky	
	Bt1	15-32	7.5YR 3/3.5	Moderate coarse angular blocky	Broken thin cutans; many coarse interstitial pores
	Bt2	32-50	7.5YR 3/4	Moderate coarse angular blocky	Continuous moderately thick cutans; common very coarse interstitial pores
	Bt3	50-71	7.5YR 3/4	Weak, coarse, angular blocky	Broken thin cutans; few very coarse interstitial pores
	Btg	71-101	7.5YR 3.5/4	Weak, coarse, angular blocky	Patchy thin cutans
Forest (NF-2)	O_1 (L)	8-2	-	-	
	O_2	2-0	-	-	
	A	0-5	10YR 3/3.5	Strong, fine medium and coarse angular blocky	Many mycelia; many mycorrhi zae
	E	5-12	10YR 4/5	Strong coarse angular blocky	Very few small spherical red ironstone and hard spherical black iron-manganese nodules; common mycelia on peds
	Bten1	13-30	10YR 4.5/6	Strong coarse angular blocky	Very few small spherical red ironstone and hard spherical black iron-manganese nodules; many mycelia on peds; broken moderately thick cutans
	Bten2	30-49	10YR 4/6	Weak coarse angular blocky	Few small soft spherical red ironstone and very few small hard spherical black iron-manganese nodules; common mycelia on peds; broken moderately thick cutans
	Bt1	49-69	10YR 5/6	Very weak coarse angular, blocky	Few mycelia on peds, broken thin cutans
	Bt2	69-100	10YR 5/6	Massive	Very few small soft spherical red ironstones, nodules; partly thin cutans

Table 2. continued.

Soil	Horizon	Depth (cm)	Color (moist)	Structure	Other notable features
Grass-land (GL-2)	O	-	-	-	Continuous hard thin blackish brown crusts, probably of algae, on soil surface
	A	0-5	10YR 3/3	Weak coarse angular blocky	
	E	5-10	10YR 3.5/4	Strong medium coarse angular blocky	
	Bt1	10-32	10YR 4/6	Strong coarse angular blocky	Many very coarse interstitial pores; patchy thin cutans
	Bt2	32-52	10YR 4/6	Moderately coarse angular blocky	Very few small soft spherical red ironstone nodules, continuous moderately thick cutans on peds; common, very coarse interstitial pores
	Bt3	52-69	10YR 4/6	Weak coarse angular blocky	Broken moderately thick cutans on peds; few very coarse interstitial pores
	Btg	69-100+	10YR 4.5/6	Massive	Patchy thin cutans

Adapted from Ohta (1990a)

Table 3. Physical properties of forest and adjacent grassland soils in Carranglan, Nueva Ecija.

Soil	Depth (cm)	Bulk density (g/ml)	Pore space (%)			Moisture content (%)	Hydraulic conductivity (ml/min)
			fine	coarse	total		
Forest	0-5	0.84	34	33	67	26	32
	5-10	1.07	48	18	66	36	42
	25-30	1.49	38	9	47	19	2
	65-70	1.35	39	13	52	24	2
Grass-land	0-5	1.19	30	25	55	7	19
	5-10	1.28	32	22	54	14	13
	25-30	1.48	37	11	48	20	2
	65-70	1.43	40	12	52	23	3
Forest	0-5	0.84	36	30	66	30	134
	5-10	1.20	43	13	56	30	18
	25-30	1.29	38	15	54	28	6
Grass-land	0-5	1.06	29	31	60	8	24
	5-10	1.20	22	33	55	9	24
	25-30	1.32	35	17	52	20	10

Adapted from Ohta (1990a)

Soil Mechanical Composition and Clay Mineralogy

The mechanical composition of the forest and grassland soils was basically similar in both plots (Table 4). Comparison of the forest and grassland soils revealed that the clay content of the top horizon was lower in the forest than in the grassland. The ratio of the clay content for the top horizon to the maximum value within the argillic B horizons was 1.76 and 1.47 for the 2 forest soils, compared with 1.44 and 1.20 for the corresponding grassland soils. The higher ratios in the forest soils

Table 4. Mechanical composition of forest and adjacent grassland soils in Carranglan.

Soil	Horizon	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Texture
Forest NF-1	A	21.7	19.5	28.5	20.8	CL
	E	21.9	21.0	30.1	20.6	CL
	Bt1	30.2	16.3	31.3	20.5	LiC
	Bt2	34.2	17.2	27.4	19.8	LiC
	Bt3	38.1	16.9	24.4	17.7	LiC
	Btg	37.0	20.3	25.3	17.8	LiC
Grass-land GL-1	A	26.7	17.3	37.2	14.6	LiC
	E	29.5	18.1	36.7	14.4	LiC
	Bt1	33.5	17.7	35.0	13.3	LiC
	Bt2	35.4	20.4	30.1	13.5	LiC
	Bt3	38.4	23.1	25.0	12.5	LiC
	Btg	33.2	22.5	27.5	14.6	LiC
Forest NF-2	A	30.7	24.1	13.9	24.3	LiC
	E	41.8	23.1	13.5	21.8	LiC
	Bt1	44.9	27.3	12.1	17.9	LiC
	Bt2	45.0	24.0	12.8	17.7	HC
	Bt3	38.4	31.3	11.5	20.0	LiC
	Btg	36.8	32.1	12.6	18.1	LiC
Grass-land GL-2	A	35.2	23.5	16.9	24.1	LiC
	E	39.0	21.4	15.1	22.1	LiC
	Bt1	42.2	21.7	15.6	19.9	LiC
	Bt2	42.1	23.6	16.5	18.5	LiC
	Bt3	40.5	25.1	16.2	18.7	LiC
	Btg	38.6	27.1	16.4	19.4	LiC

Adapted from Ohta (1990a)

Table 5. Clay mineral composition of forest and adjacent grassland soils in Carranglan.

Soil	Horizon	Kaolinite	Montmorillonite	Vermiculite	Al-vermiculite
NF-1	A-Btg	++	+	+	+/-
GL-1	A-Bt1	++	+	+/-	
	Bt2-Btg	++	+/-	+	
NF-2	A-Bt2	++++		+/-	
GL-2	A-b	++++		+/-	

X-ray reflection intensity: ++++ = very strong; ++ = moderate; + = weak; +/- = trace.
Adapted from Ohta (1990a)

may suggest the existence of a stronger clay eluviation in the soil under forest cover due to greater hydraulic conductivity than under grassland. The clay content of the surface soil of the grassland may have increased due to the enhancement of the truncation of sandy topsoils after deforestation.

Clay mineral composition of the two types of soils is summarized in Table 5. The forest and grassland soils belonged to the same kind of soil in terms of genesis, and prolonged grassland conditions following deforestation had not appreciably affected clay mineralogy.

Soil Chemical Properties

Table 6 summarizes some chemical parameters of the two soils. The forest soil (NF-1) showed higher pH (H_2O) values than the grassland soil (GL-1) throughout the sola, the difference being particularly conspicuous in the A and E horizons. This indicates that acidification of the A horizon and sometimes of even the E and Bt horizons had taken place in the grassland soils.

The carbon content of the A horizon was significantly higher in the forest soil than in the grassland soil by 104 and 43% for Plot-1 and Plot 2, respectively (Table 6). There were differences also in the nitrogen content between the forest and grassland soils. These findings suggest that deforestation and the subsequent prolonged grassland conditions had resulted in a distinct decrease in amount of organic matter of the surface soil due to the lower supply and more rapid consumption of organic matter. However, the carbon and nitrogen contents of the subsoils were not affected by the changes in vegetation. The differences in the vegetation conditions affected the C:N ratio of the soil. In both plots, the values were clearly lower in the A and E horizons of the forest soils than in those of the grassland. This may be associated with the higher soil fauna activity in the forest soils, promoted by the steady supply of organic matter to the soils and better soil environment in terms of acidity and moisture conditions. This also implies that in the grassland soils, nitrogen is depleted and removed from the system more extensively through leaching and repeated burning than in the forest soils.

Table 6. Chemical characteristics of forest and adjacent grassland soils in Carranglan.

Soil	Hori-zon	pH		C	N	C/N	CEC (meq/ 100g)	Exch. Base (meq/100g)				Base Satur-ation	Avail-able P (P_2O_2 ppm)
		H_2O	KCL	(%)	(%)			Ca	Mg	K	Na		
Forest NF-1	A	6.48	5.69	4.65	0.34	13.6	32.5	27.1	6.00	0.89	0.35	105.4	52.4
	E	6.69	5.64	3.14	0.28	11.4	29.4	21.0	5.24	0.67	0.89	94.5	16.1
	Bt1	6.19	4.69	1.35	0.13	10.2	22.4	13.6	4.13	0.71	1.19	87.5	5.7
	Bt2	6.11	4.30	0.73	0.08	9.5	21.6	13.2	4.38	0.68	1.06	89.4	3.4
	Bt3	6.32	4.41	0.64	0.07	9.7	24.1	15.6	4.32	0.20	0.28	84.7	3.0
	Btg	6.42	4.41	0.53	0.06	8.6	25.9	17.7	4.20	0.18	0.29	86.5	5.0
Grass-land GL-1	A	5.70	4.32	2.27	0.13	17.5	22.6	9.25	6.18	0.62	0.22	72.1	7.3
	E	5.42	3.92	1.75	0.11	15.8	22.7	9.11	5.79	0.59	0.58	70.9	3.4
	Bt1	5.55	4.01	1.13	0.09	12.8	23.6	10.5	6.88	0.78	1.48	83.4	1.4
	Bt2	5.80	4.20	0.64	0.06	10.4	24.8	11.7	7.58	0.56	0.71	82.8	1.0
	Bt3	6.10	4.29	0.45	0.04	11.3	27.2	14.0	8.22	0.49	0.74	86.4	0.6
	Btg	6.17	4.30	0.40	0.04	10.1	27.4	14.4	7.80	0.47	0.99	86.5	1.4
Forest NF-2	A	6.09	5.25	3.19	0.25	12.7	17.3	14.0	5.79	0.66	0.99	123.9	9.1
	E	5.21	4.00	0.90	0.07	12.9	8.20	2.25	2.31	0.43	0.53	67.3	1.7
	Bt1	5.02	3.89	0.51	0.04	14.1	8.27	1.22	1.66	0.12	0.42	41.5	1.0
	Bt2	4.93	3.80	0.65	0.04	15.1	8.35	1.19	1.82	0.96	0.89	58.2	1.4
	Bt3	5.08	3.90	0.32	0.03	12.8	7.88	1.82	1.21	0.32	0.45	48.2	1.0
	Btg	5.20	3.98	0.29	0.02	12.1	8.07	2.76	1.26	0.10	0.45	56.6	0.6
Grass-land GL-2	A	5.40	4.30	2.23	0.15	14.8	9.64	2.37	1.59	0.53	0.37	50.3	8.3
	E	4.99	3.91	1.59	0.11	14.9	8.66	1.58	0.55	0.14	0.50	32.0	2.9
	Bt1	4.90	3.93	1.03	0.07	14.1	7.79	1.28	0.46	0.32	0.42	31.8	1.4
	Bt2	5.10	3.99	0.62	0.05	13.2	6.50	1.51	0.38	0.19	0.23	35.5	1.0
	Bt3	5.13	4.00	0.49	0.04	12.6	6.74	1.58	0.35	0.35	0.47	40.7	0.2
	Btg	5.20	4.05	0.43	0.03	12.6	6.74	1.84	0.43	0.36	0.48	46.2	0.2

Adapted from Ohta (1990a)

The cation exchange capacity (CEC) value of the A horizon was higher in the forest soil than in the grassland soil in each plot, while in the underlying horizons the values did not differ (Table 6). The higher carbon contents may be responsible for the higher CEC in the surface soils of the forest. The forest soil showed higher exchangeable Ca^{2+} contents than the grassland soil for the upper horizons. There was no consistent pattern in the exchangeable Mg^{2+}. Slightly higher exchangeable Na^+ and K^+ were observed between the forest and grassland soils. The forest soil showed high base saturation percentages for the

A and E horizons compared with the corresponding horizon in the grassland soils. Deforestation and subsequent prolonged grassland conditions are likely to have caused the deterioration of the base status in the surface soils particularly in the case of exchangeable Ca^{2+}.

Available phosphorus (P) concentration, which was highest in the A horizon, decreased with depth; however no clear change of the value was noticed within the B horizon (Table 6). The exceptionally high value of the available P content in Plot 1 (52.4 ppm) was observed in the A horizon of the forest soil which contrasted with a modest 7.3 ppm in the corresponding horizon of the grassland soil.

Forest soils contained 5 to 10 times more available nitrogen than the grassland soils in the A and E horizons in Plot-1 and in the A horizon in Plot-2. The formation of inorganic nitrogen was less abundant in the A horizons of the grassland soils than in those of the forest soils. Nitrification rate was also higher (70.2-99.7%) in the forest soils. Deforestation impeded nitrification through the decline of soil acidity. Thus forest soils were more fertile than grassland soils in terms of available nitrogen, especially in the surface soil. Nitrogen in the grassland soil was depleted and removed from the system by repeated burning and less efficient utilization by grasses during a long period of time, thus the proportion of the nitrogenous compounds relatively resistant to microbial attack was higher in the soils under grassland conditions.

<u>Soil Humus Composition</u>

The patterns of humus composition revealed that the extraction rate (Ce/Ct) was slightly higher in forest soils than in grassland soils. This pattern was associated with the lower supply of fresh organic materials and more rapid decomposition of soil organic matter in the grassland soils. Forest soils contained low humified humic acid, especially in the surface horizons because a large amount of fresh organic matter was supplied continuously. In the grassland soils, however, the humification of humic acids proceeded to a greater extent, especially in the upper layers because they contained highly humified humic acid with a higher resistance to microbial attack due to the lower supply and prolonged decomposition of organic matter. Repeated burning may also result in highly humified humic acid in grassland soils.

Ohta (1990a) concluded that deforestation and subsequent prolonged grassland condition alters soil properties, particularly in the surface soils. After removal of forest cover, the topsoil temperature rises and steady inputs of organic matter and other nutrients are interrupted. As a result, organic matter in the topsoil rapidly decomposes, and the nutrients released are partially absorbed by the grass, while excess nutrients (particularly calcium and nitrogen) are lost by leaching and increased erosion, without sufficient replenishment. Repeated burning of grass further quickens the nitrogen loss from the system. The depletion of organic matter, base status, and soil acidity decreases soil fauna activity. Meanwhile, the decrease in nitrogen fixation may accompany soil deterioration. Reduced organic matter content, base status, and fauna activity may decrease the soil aggregate stability, resulting in deteriorated soil physical properties and decreased infiltration. The resultant increased runoff and erosion may further accelerate the depletion of organic matter and nutrient status. As a consequence, the topsoil of the grassland eventually contains organic matter more resistant to the attacks of microorganisms, evidenced by the lower nitrogen availability and the higher humification of humic acid compared to the forest soil.

Ohta (1990a) further concluded that in order to interrupt the vicious cycle of deterioration in the soil quality and to conserve grassland soils, it is essential to: protect the soil surface from erosion hazards, increase the content of organic matter and nitrogen, and improve the base status of the soil. Planting the area with fast-growing, nitrogen-fixing trees appears to be one of the most sensible strategies to achieve this objective.

Effects of Reforestation with* Acacia *Species on Degraded Grassland Soils

Of the many studies available on the effects of reforestation of degraded grasslands with *Acacia* species, three are presented here.

Case Study 1

Ohta (1990b) studied the influence of grassland reforestation on soils in plantations of 5-year-old *Acacia auriculiformis* and 8-year-old *Pinus kesiya.*

Soil Morphology

Table 7 summarizes the morphological characteristics of the O and Au1 (or A) horizons. In both plots, O horizons of the plantation soils consisted of a L layer or L and thin F layers. In contrast, both grassland soils lacked the O horizon altogether. The soil structure in the topsoil was more highly developed in the plantations than in the grasslands. In Plot-1, the surface soil of the plantation (F-1) contained a large number of fine roots of *Acacia* and earthworm casts; the adjacent grassland (G-1) showed no remarkable evidence of soil fauna activity. Acacias' well-developed root system is considered to reduce the risk of soil erosion. On the other hand, in the *Pinus* plantation, no such strong soil animal activity was noticed. Many mycelia were found in the topsoil of the *Pinus* plantation (F-2), but they were absent in the adjacent grassland soil. *Acacia* considerably improved the morphology of the topsoil due to the enriched soil fauna activity and well developed rooting system, whereas *Pinus* did not ameliorate it appreciably and had an adverse effect due to the presence of mycelia. The differences in tree leaf characteristics, which control soil fauna activity, and in the root system seem to be most closely related to the morphological improvement of the soils under tree growth.

Soil Physical Properties

Bulk densities for the 0-5 cm layer of the plantation soils were distinctly lower (1.2 and 1.23 g/ml) than those of the grassland soils (1.32 and 1.35 g/ml) (Table 8). The bulk density of the 5-10 cm layer was lower in the plantation soil than in the grassland soil in Plot-1, whereas it was similar in Plot 2. Fine pore percentage slightly increased from 0-5 to 5-10 cm layers, while the coarse pore percentage decreased with depth in each soil. The percentage of fine and coarse pore spaces for the 0-5 cm layer was slightly higher in the soil under tree

Table 7. Morphological changes of the surface grassland soil after establishment with *Acacia auriculiformis* and *Pinus kesiya* plantation in Carranglan.

Plot	Soil	O Horizon	Au1 or A Horizon	
			Structure	Other features
Plot 1	Grassland G-1	No O horizon	Very weak medium and coarse blocky and weak, very fine granular in uppermost part	Continuous thin soil crusts on the soil surface
	Acacia plantation F-1	2 cm thick L and F layers	Strong fine and medium blocky and moderate very fine and fine granular in the uppermost part	Common worm casts on the soil surface; abundant fine roots of *A. auriculiformis*
Plot 2	Grassland G-2	No O horizon	Weak medium subangular blocky and fine granular in the uppermost part	
	Pinus plantation F-2	2 cm thick L layer; no F layer	Strong medium and coarse subangular blocky and moderate fine granular in the uppermost part.	Abundant mycelia in the upper part and many mycelia in the lower part.

Adapted from Ohta (1990b)

growth than in the grassland in both plots. The total pore space percentage of the 0-5 cm layer was higher for the plantation than for the grassland in both plots, though the values for the 5-10 cm layer were similar in the soils under different cover types.

Moisture content of fresh samples of the grassland soils was very low (2-6%) in the 0-5 cm layer (Table 8). In contrast, moisture content of the plantation soil gave higher figures in the range of 9-12%. The soils of the tree plantations retained more water than the grassland by 40-55 t/ha respectively in Plot-1 and Plot-2 in the 0-10 cm layer during the dry season.

Hydraulic conductivity ranged widely from 3 to 50 ml/min and was affected by reforestation depending on the tree species (Table 8). The value increased markedly with reforestation in Plot 1 (with *Acacia*), especially in the 0-5 cm layer, and agrees with the morphological characteristics such as the abundant fine roots of *Acacia* and the well-developed soil structure. In Plot 2, however, the hydraulic conductivity decreased with plantation establishement in spite of the improved soil structure. This was attributed to the water repellency acquired by the soil under *Pinus* growth, which contained many mycelia.

The soils' physical properties were significantly improved after reforestation, as indicated by the increases in bulk density and total pore

Table 8. Physical changes of the surface grassland soil after plantation establishment in Carranglan, Nueva Ecija.

Plot	Soil	Depth (cm)	Bulk density (g/ml)	Pore space (%) fine	coarse	total	Moisture content (%)	Hydraulic conductivity (ml/min)
Plot 1	Grass-land	0-5	1.32	21	28	49	2	15
		5-10	1.46	27	18	45	11	4
	Acacia	0-5	1.20	23	32	55	9	50
		5-10	1.32	25	22	47	11	16
Plot 2	Grass-land	0-5	1.35	25	24	49	6	18
		5-10	1.44	27	19	47	10	6
	Pinus	0-5	1.23	29	25	54	12	10
		5-10	1.43	34	13	48	14	3

Adapted from Ohta (1990b)

space distribution (Table 8). The improvement of the physical properties, however, seems to be limited to the thin surface soils. The promotion of the soil fauna activity by steady organic matter supply and improved soil environment, and the dense distribution of tree roots of *Acacia* may account for the physical improvement of the surface soils. But *Pinus* plantations may have an adverse effect on infiltration due to mycelial development.

Soil Chemical Properties

The pH values (H_2O and KCl) both decreased significantly with reforestation in the 0-5 and 5-10 cm layers. pH of the surface soil in plantations was lower than the grassland soils, contrary to expectations. Ohta (1990b) ascribed the lower pH in the plantation soils to increased production of organic acids associated with accelerated organic matter decomposition, and partly to the decrease in the content of exchangeable cations associated with intensive uptake by the trees and soil fauna.

Total carbon and total nitrogen contents significantly decreased with reforestation in the 0-5 and 5-10 cm layers of Plot 1and in the 0-5 cm layer of Plot 2. The decrease was observed only in plantations at the early stage of tree growth, as soil organic matter level tends to build up as the forest grows older.

Ohta (1990b) concluded that reforestation affected the nutrient dynamics of the plant-soil system by causing a significant decrease in pH values, carbon and nitrogen contents, CEC, and exchangeable Ca^{2+} of the surface soils during the early stages of tree growth. As the planted trees grow, they supply increasing amounts of fresh organic matter rich in mineralizable nutrients to the soil due to the increase in biomass production. Trees improve soil moisture by providing shade. The resultant enhancement of soil fauna activity promotes organic matter decomposition and decreases the contents of total carbon and nitrogen in the surface soils, because the organic matter replenishment is not large enough to exceed mineralization during the early stage of the plantations. Enhanced activity of the soil fauna also improves soil physical properties. The reduction in organic matter content results in decreased CEC.

Case Study 2

The effects of *Acacia auriculiformis* and *Gmelina arborea* plantations on soil properties of a degraded grassland were studied by Dela Cruz and Luna (1992). Contiguous stands of eight- (Aa8) and two-year-old (Aa2) *A. auriculiformis* and eight-year-old (Ga8) *G. arborea* were selected, along with an adjacent grassland. Average heights at the end of the study were 980, 230, and 260 cm; diameter at breast height was 15, 3.5, and 5.6 cm, respectively for the three stands. The crowns of Aa8 were almost closed and the forest floor was covered with thick litter, which was absent in the Aa2 and Ga8 stands.

Litterfall and Leaf Litter Decomposition

Records of the mean monthly litterfall in the three stands show that, except for two months, Aa8 consistently produced the greatest amount of litter. Total annual litterfall in the older *A. auriculiformis* plots amounted to 1338 kg/ha, while that of *G. arborea* plots of the same age was only 408.5 kg/ha.

Litter decomposed fastest in the *Gmelina* plots, followed by the Aa8 and Aa2 plantations. The high decomposition rate in Ga8 was partly due to the high activity of termites under the stand. The faster litter decomposition under the older acacia plantation versus the younger plot was attributed to the favorable microclimate and probably to the presence of more active soil flora and fauna.

Soil Bulk density

A marked improvement in bulk density among stands was observed, with *Acacia auriculiformis* improving soil bulk density better than *G. arborea.* This is probably due to the higher organic matter content and biological activity of the stands, particularly in the *A. auriculiformis* plots. Bulk density values for the Aa8, Aa2, Ga8, and grassland soils were 1.32, 1.41, 1.52 and 1.56 g/cc, respectively.

Soil Moisture

Soil moisture content during the dry months was improved in the Aa8 stand. The thick litter under this stand reduced evaporation from and increased moisture retention in the surface soil. Furthermore, the lower air and soil temperatures and higher relative humidity in that stand minimized soil moisture losses. These influences were nil in the *Gmelina* stand, where there was much less litter and it decomposed more quickly.

Soil pH

Initially, fluctuations in pH values occurred with no marked variations. After a fire razed the area, the pH values of the Aa8 and Aa2 soils peaked to 6.5

and 5.7, respectively, above the values for the grassland and unburned Aa8 plots. This was attributed to the deposition of bases-rich ash, particularly in both acacia plots. After 11 months, effects of fire on soil pH was no longer evident as heavy rainfall had washed away the ash.

The unburned Aa8 plot generally had the lowest pH values, perhaps due to the increased production of organic acids associated with accelerated organic matter decomposition and the more favorable microclimate in this stand.

Soil Organic Matter

Organic matter content was generally higher under the older *Acacia* stand, followed by *Gmelina*, the younger *Acacia* stand, and grassland soil (Figure 1a). This trend reflected the amount of litterfall in the plantations, absence of litter in the grassland, and possibly variations in activities of soil organisms.

Total Nitrogen

Total soil nitrogen content was most improved under Aa8 (Figure 1b), due to its high amount of N-rich litter derived from associated N-fixation. The improved microclimatic conditions favored the activity of N-fixing organisms in this legume. The soils under Ga8 and Aa2 exhibited higher N contents than the grassland soil. Analysis found Aa8 litter to contain 1.56% N. At a litterfall rate of 1338 kg/ha/year, this leads to an estimated total litterfall-added N of about 20.87 kg/ha/year.

Available phosphorus

Availability of phosphorus (P) was enhanced under Aa8 (Figure 2a). This reflected a well developed mycorrhizal association which enabled more efficient P uptake from the P-deficient soil. Mycorrhiza increase P uptake by secreting oxalates which bind with precipitating cations (aluminum, iron, and manganese), thus releasing phosphate ions into the soil solution. Another possible mechanism is a greater activity of phosphatase enzymes, which release organic P into available forms. Analysis of litter P content showed 0.18% for both Aa8 and Ga8, leading to estimated P return from litterfall of 2.41 and 0.73 kg P/ha/year, respectively.

Exchangeable K, Ca and Mg

Soil exchangeable K exhibited seasonal fluctuations in all sites (Figure 2b). Burning markedly increased exchangeable K in the Aa8, Aa2 and grassland plots due to deposition of bases-rich ash on the soil surface. Exchangeable Ca and Mg of the soils at the four sites also fluctuated over time. Values were generally lower under Aa8 and Ga8 than under Aa2 and grassland area. This decrease in exchangeable K, Ca, and Mg suggests that they are intensively absorbed by the actively growing trees and soil fauna, particularly during early growth.

Case Study 3

Chakraborty and Chakraborty (1989) studied changes in soil properties under two-, three-, and four-year-old

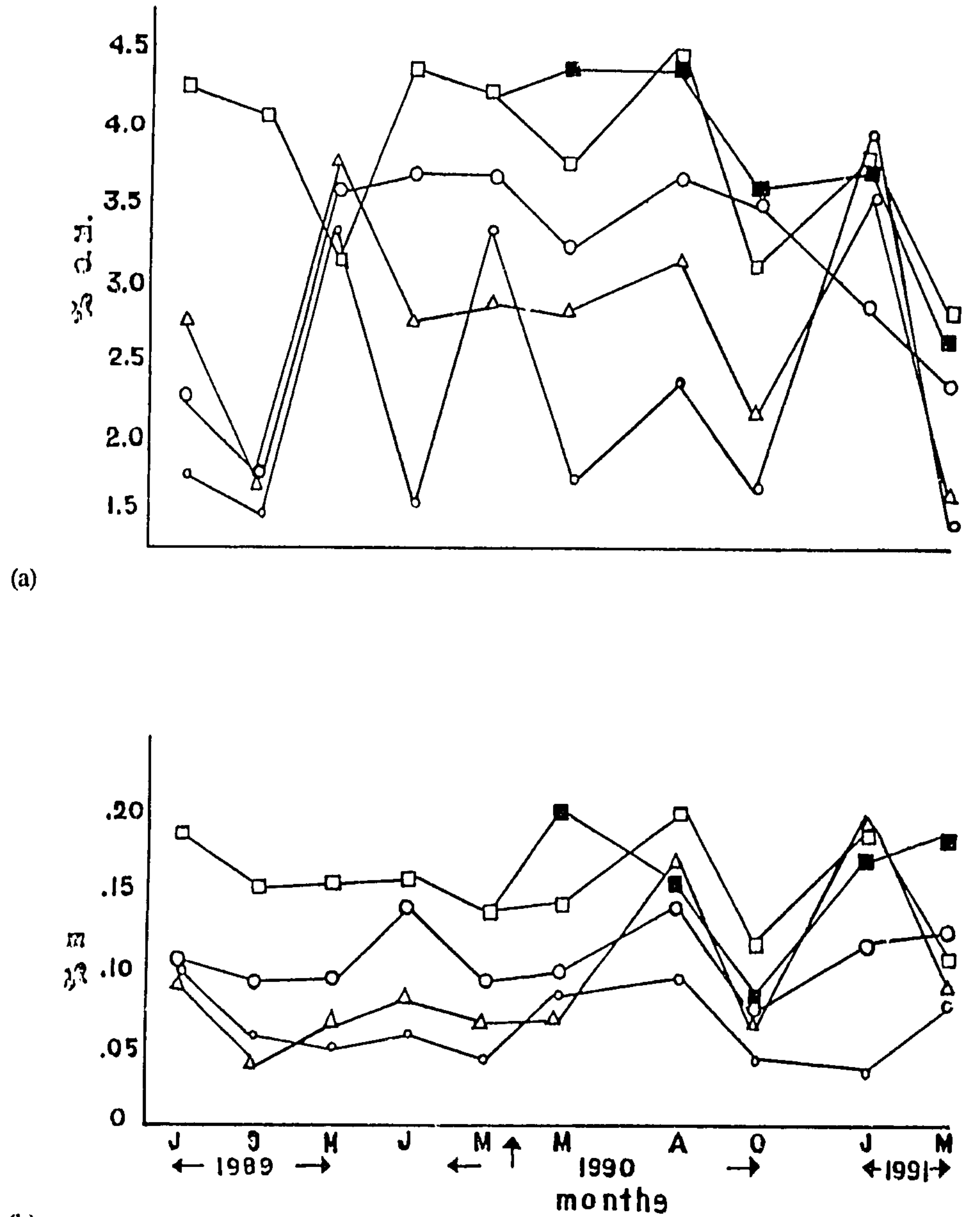

Figure 1. Bimonthly values of (a) organic matter and (b) total nitrogen under *A. auriculiformis, Gmelina arborea,* and grassland at 0-5 cm depth. *Source:* Dela Cruz and Luna 1992

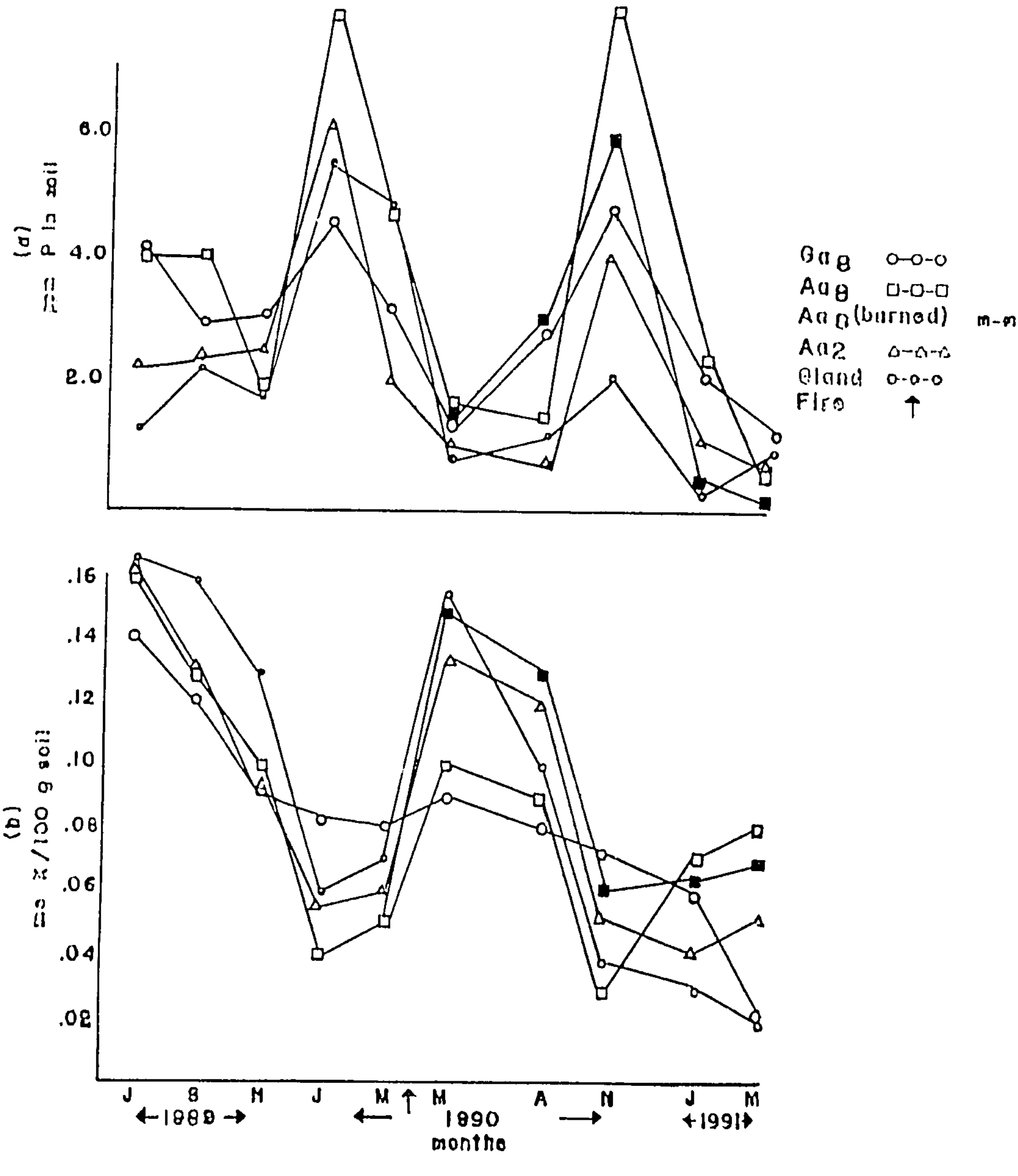

Figure 2. Bimonthly values of (a) soil-available phosphorus and (b) exchangeable potassium under *A. auriculiformis*, *Gmelina arborea*, and grassland at 0-5 cm depth. *Source:* Dela Cruz and Luna 1992

A. auriculiformis plantations in Tripura West, India. Soil pH increased from 5.9 (in barren soil), to 6.7 at ages two and three years, and to 7.6 at age four years (Table 9). Under the same plantations, electric conductivity increased from 27.2 to 48.4 mhos/cm; water-holding capacity increased from 0.364 to 0.504%; and potassium content increased from 0.81 to 2.70%; nitrogen increased from 0.364 to 0.504%; and potassium content increased from 5.45 to 7.10 mg/lit. The significant changes in physico-chemical properties particularly in the 3-4 year old plantations were attributed to the species' fast growth, high increase in biomass production, and fast rates of leaf litter return. Increase in nitrogen may also be attributed to the trees' N-fixation.

Control of Surface Soil Erosion

Wiersum (1983) summarizes the protective role of vegetation against surface soil erosion:

1. Rainfall interception decreases the quantity of water reaching the soil and alters the spatial distribution of that water through stem flow and throughfall, with concentrated drip points.
2. Leaves break the initial erosive power of rain.
3. Surface vegetation and litter protect the soil directly against the erosive force of falling waterdrops and surface runoff. Vegetation and litter also prevent the clogging of soil pores, which would decrease infiltration and increase surface runoff.
4. Decomposition of tree leaf litter increases the topsoil's humus content, creating optimal conditions for water permeability and general aggregate stability.

Thus vegetation affects both the erosive agents—rainfall and soil—by influencing the properties of the two media.

Wiersum (1983) studied the effects of various vegetation layers in an *A. auriculiformis* forest plantation on surface erosion in Java, Indonesia. Throughfall within the plantation was 80.4% of gross rainfall and stemflow was 7.8%. Thus net rainfall in the plantation was 88.2% of the incident rainfall. He observed that many throughfall drops

Table 9. Physico-chemical properties of soil under *A. auriculiformis* plantation.

Treatment	Color	pH	Water-holding Capacity (%)	Organic Carbon (%)	Nitrogen (%)	Potassium (mg/lit.)
Control	10 YR 6/4	5.9	27.2	22.9	0.364	5.45
2 years	10 YR 7/4	6.7	29.5	0.96	0.370	5.85
3 years	7.5 YR 5/2	6.7	43.4	2.27	0.462	6.60
4 years	7.5 YR 5/4	7.6	48.4	2.70	0.504	7.10

Adapted from Chakraborty and Chakraborty (1989) were distinctly larger than raindrops.

In addition to throughfall, some precipitation reaches the forest floor as stemflow, causing a local concentration of water around stems, which might cause increased runoff and rill erosion. The author showed that the presence of a direct soil cover is the single most important vegetation factor protecting the soil. The sustained presence of litter is ensured by the litter production capacity of the tree canopies. This litter decomposes gradually, resulting in increased humus and decreased erodibility.

Wiersum (1983) concluded that the protective influence of forest vegetation on surface soil erosion depends mostly on the vegetation's influence on the interface between erosive agent (rainfall) and the eroded medium (soil), rather than on its direct influence on these two properties. The effect of trees on rainfall has a variable and often negative effect, while the positive effect of humus incorporation on the soil will be developed over longer periods. It is the proper functioning of the forest ecosystem, rather than the presence of trees, that is important for erosion control.

Water Conservation

In preparing the current paper, the author found nothing in the literature concerning the effects of *Acacia* plantation on water conservation, water absorption rates by trees, evapotranspiration rates, effects of plantations on water quality, on water yield, and other water-based parameters. These are large gaps in *Acacia* research.

Nutrient Storage and Release

Effect on Soil Nitrogen Mineralization

Bernhard-Reversat (1988) compared the rate of soil nitrogen mineralization under a *Eucalyptus camaldulensis* plantation and a natural *Acacia seyal* forest in Senegal. The *Acacia* forest had consistently higher organic carbon and nitrogen content at all soil depths compared to that under *Eucalyptus* plantations. Mineralizable nitrogen, measured by 20 days *in vitro* incubation, averaged 40-50 ppm in *Acacia* soil and 11-14 ppm in *Eucalyptus* soil, and reached 3.5 and 2.3%, respectively, of total N. Mineralization was related to precipitation, and ranged from 18 to 40 ppm over 4 weeks during the rainy season in the *Acacia* stand, where 7-10% of total N was mineralized each year. Under *Eucalyptus* stands, N mineralization reached only 10 ppm over 3 weeks in the beginning of the rainy season, and then decreased sharply. This study showed that a legume forest (*A. seyal*) contained more carbon and nitrogen and had a higher rate of nitrogen mineralization than a *E. camaldulensis* plantation.

Venkataramanan et al. (1983) studied the chemical composition and total quantity of leaf litter from plantations of *Eucalyptus globulus* and *Acacia mearnsii* in Tamil Nadu, India. *E. globulus* leaf litter added 1935 kg/ha annually, while *A. mearnsii* added 960 kg/ha. The authors concluded that recycling of nutrients in both plantations keeps the land highly fertile, with rich top soil and dense vegetation.

Conservation of Soil Micro- and Macrofauna

Niijima and Yamane (1991) studied the effects of reforestation on soil fauna, using stands of *Leucaena leucocephala, Gmelina arborea, Pinus kesiya,* and *Acacia auriculiformis* established in a degraded grassland. Grassland tracts with *Themeda triandra* (samon) and *Imperata cylindrica* (cogon), and parts of a natural dipterocarp forest, were selected as controls. In each stand, soil animals, microarthropods, and microfauna (including earthworms) were determined.

Soil Microarthropods

Figure 3 shows the vertical distribution of soil microarthropods in each vegetation type. The numbers of Collembola and Hemiptera decreased during the dry season. The number of mites decreased in the dry season in the *Acacia* plantation, while it was almost the same in both seasons at the other plots. The reforested stands had relatively large populations of microarthropods in the wet season. On the other hand, there were few microarthropods in the samon grasslands and the natural forest.

Soil Macrofauna

Figure 4 shows the vertical distribution of soil macrofauna. In the dry season, soil macrofauna was found mainly in the 0-5 cm or 5-10 cm soil layers. In the wet season, soil macrofauna was found mainly in the uppermost 0-5 cm soil layer with the exception of ants in *G. arborea.*

Earthworms were the dominant group among macrofauna (Figure 5), and were found in almost all plots in the wet season, while in the dry season, they were found only in the forested plots. Egg capsules of earthworms were found in the forested plots in both seasons, in the *Imperata* grassland only in the wet season, and none in the samon grassland. The earthworms, consisting of one species of Megascolides and two species of Lumbricidae, seemed to live in the forest during the dry season and spread their distribution to grasslands during the wet season.

Termites were abundant in plots 1, 2, and 3 in the dry season. Some termite mounds with 60-100 cm in diameter and 35-100 cm in height were observed at *Acacia* stands. The material for the mounds appeared to come from the soil at 50 cm below the surface.

Reforestation enriched the Class or Order composition of soil macrofauna. The number of Class or Order of macrofauna was 3-5 at the Samon grassland, 6-9 at the Samon grassland with *G. arborea* or with *Acacia*, 5-10 in *Imperata* grassland, and 8-13 in the forests.

Total number of soil macrofauna was 6,864 individuals/m^2 in maximum at the Samon grassland with *G. arborea*, where ants were abundant. Total biomass was 41.3 g/m^2 in maximum at the *Acacia* plantation in wet season, where earthworms were abundant.

Cast Production by Earthworms

Earthworms deposited 40 g/m^2/day (air dry weight) of casts in the *Imperata* grassland, 11 g/m^2 in the *G. arborea* plantation, and 29 g/m$_2$ in the *Acacia* plantation. These correspond to 5.2, 1.4, and 1.1 g/standing crop of earthworms (g wet weight)/day.

Niijima and Yamane (1991) concluded that reforestation of

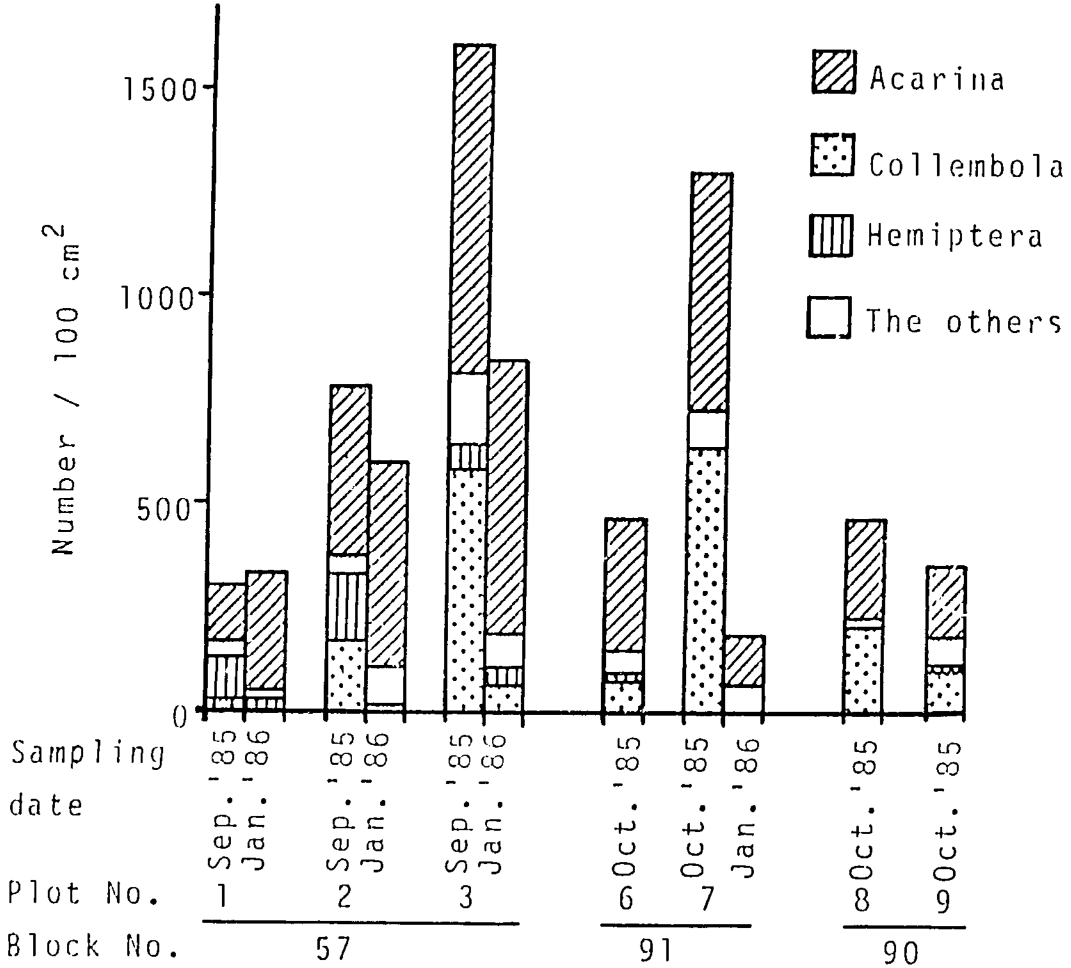

Figure 3. Number of soil microarthropods per 100 cm^2, 0-10 cm depth at the samon grasslands (plots 1, 6, and 8), the *Imperata* grassland (plot 2), the *Leucaena* plantation (plot 3), the *Acacia* plantation (plot 7) and natural forest (plot 9). *Source*: Nijima and Yamane (1991)

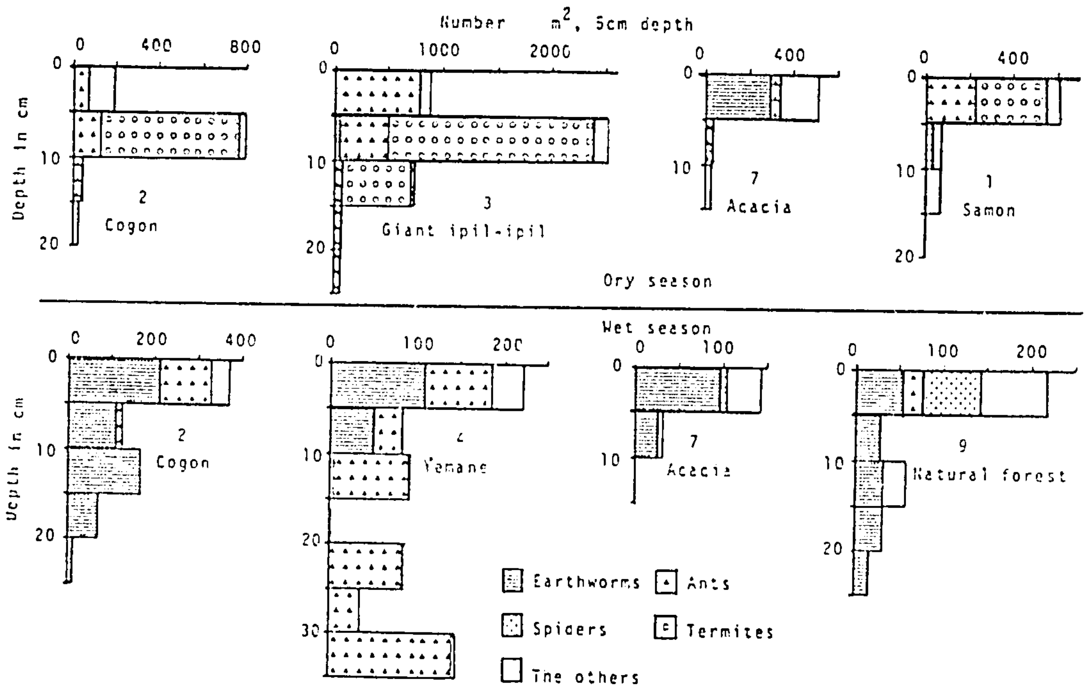

Figure 4. Vertical distribution of soil macrofauna in the dry season (Jan. 28-29, 1986) and in the wet season (Aug. 14-21, 1986) under samon grassland (plot 1), *Imperata* grassland (plot 2), *Leucaena* plantation (plot 3), yemane plantation (plot 4), *Acacia* plantation (plot 7), and natural forest (plot 9). *Source*: Nijima and Yamane (1991)

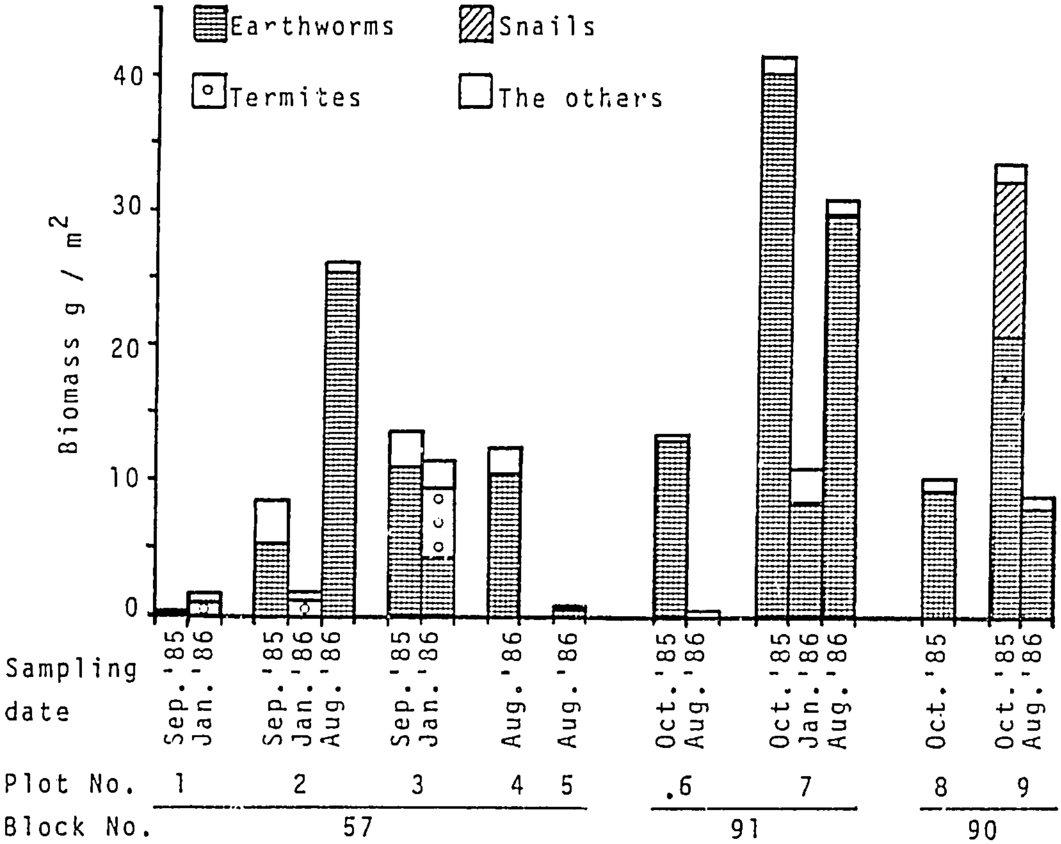

Figure 5. Biomass of soil microfauna per m2, 0-10 cm depth under samon grassland (plots 1, 6, and 8), *Imperata* grassland (plot 2), *Leucaena* plantation (plot 3), yemane plantation (plot 4), *Pinus* plantation (plot 5), *Acacia* plantation (plot 7), and natural forest (plot 9). *Source*: Nijima and Yamane (1991)

grasslands helped to reduce soil temperature during the daytime and to the increase of litter supply. These changes provide favorable environments for soil fauna, and tend to increase their numbers, biomass, and species composition (Class or Order).

Acacia trees transpired much water during the dry season, and the soil was so desiccated that the number of soil fauna, especially soil microarthropods, decreased. The soil under *L. leucocephala* seems not be as dry as the *Acacia* soil because the trees had been defoliated by *Heteropsylla cubana* and did not transpire much water.

Collembolans and earthworms were abundant only in the wet season, reflecting the moist condition in soil. These groups indicate soil conditions. Soil macrofauna, especially earthworms, enhanced litter decomposition and accelerated turnover rates of nutrients.

Microclimate Amelioration

In the study cited earlier, Dela Cruz and Luna (1992) also studied the effects of the older and younger *A. auriculiformis* and *G. arborea* plantations and an *Imperata* grassland on such microclimatic parameters, including air and soil temperature, light intensity, and relative humidity. *G. arborea* consistently showed the highest air temperature, followed by the grassland site. Lowest air temperatures were obtained in the older *A. auriculiformis* stand, with the most marked difference in air temperature occurring at 1:00 PM.

Hourly light intensity was considerably decreased in the older *A. auriculiformis* stand. Highest light intensity was observed in the grassland and the more exposed Ga8 and Aa2 plots. A peak in high light intensity was observed at 1:00 PM.

Relative humidity was generally higher in the Aa8 stands; lowest values occurred in the more exposed Ga8 and grassland areas.

Hourly variations in soil temperature among the four sites were most marked only on the soil surface (Figure 6a) and at 5 cm (Figure 6b) depths. Soil temperature was consistently highest in the grassland and Aa2 sites and generally decreased with increasing soil depth. A peak in surface soil temperature occurred at 1:00 PM.

The study suggests that species with deeper crowns and more foliage, such as *A. auriculiformis*, foster a more stable microclimate. This stability favors soil moisture conservation and better soil organic matter content due to more favorable activity of soil organisms.

In the study by Niijima and Yamane (1991), soil temperature was lower than air temperature in the forest and plantation; this was the reverse in the grasslands (Figure 7). The soil temperature in the forested areas were 2.4-5.9°C lower than those in the grasslands during daytime.

Allelopathic Effects of Acacias

Not all of the environmental effects of *Acacia* plantations are positive. Swaminathan et al. (1989) studied the effects of aqueous extracts of bark and leaf of *A. nilotica* for potential inhibitory effects on eight arable crops (sorghum, cotton, cowpea, sunflower, eggplant, tomato, chillis, and lady's finger). The extracts significantly inhibited seed germination, and also affected radicle and plumule growth.

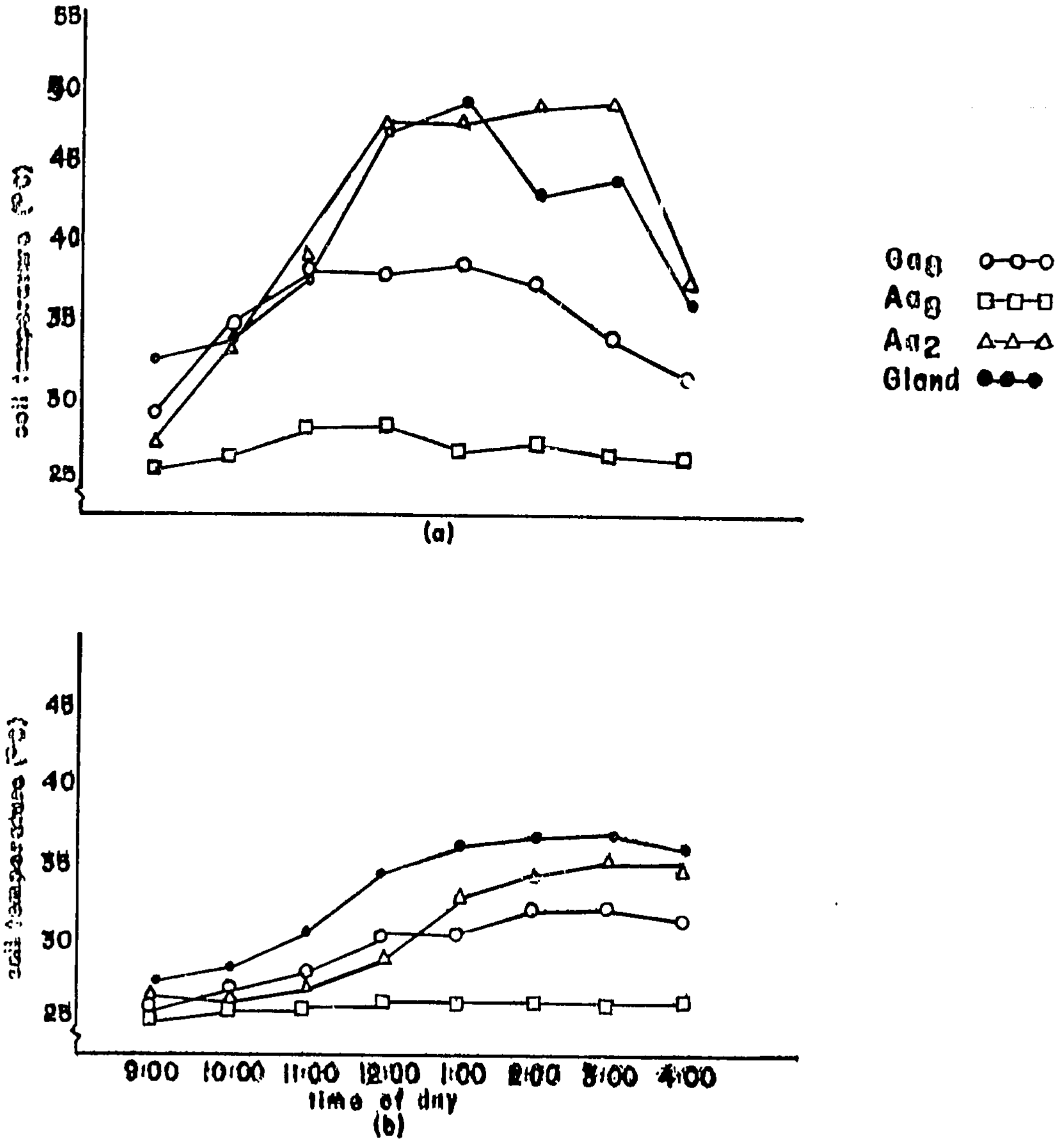

Figure 6. Soil temperature under different forest stands and grassland, measured at (a) soil surface and (b) 5 cm depth. *Source:* Dela Cruz and Luna (1992)

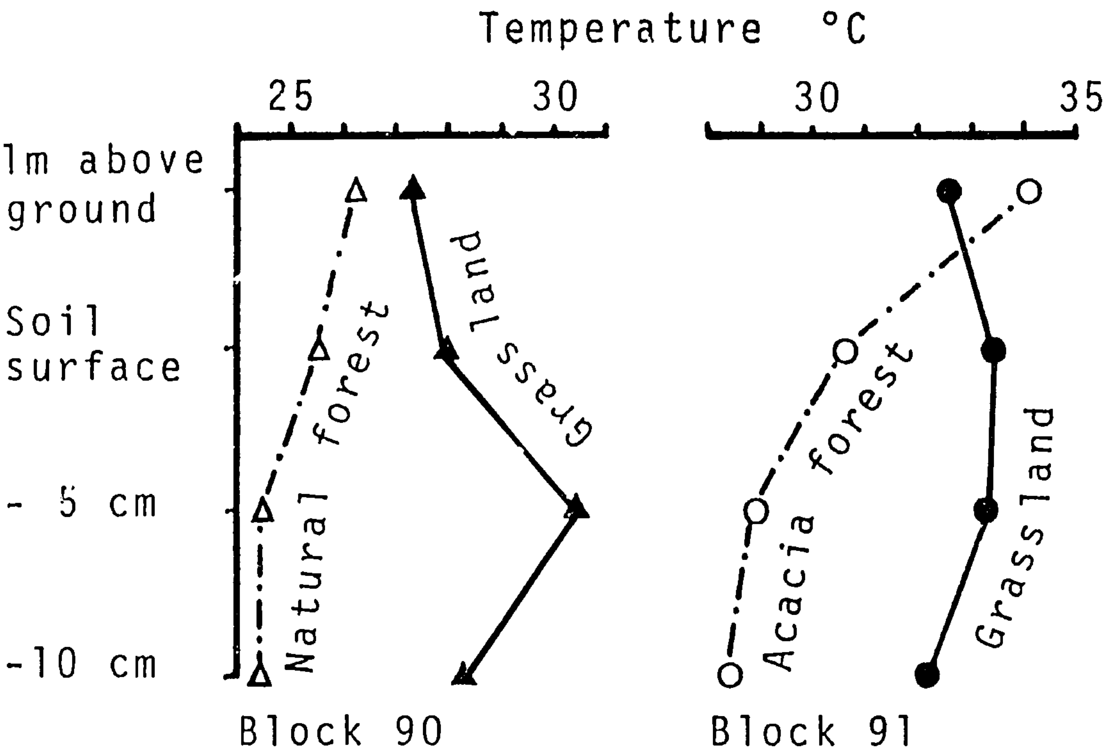

Figure 7. Vertical distribution of temperature. *Source:* Niijima and Yamane (1991)

Bark extract caused greater inhibition than the leaf extracts. It was assumed that the effective substances were phytotoxins, mostly tannin, present in the extracts. Tomato was the most susceptible crop, and sunflower was the least susceptible.

Conclusions

Can *Acacia* plantations assist in environmental conservation? Yes, data show that indeed acacias can do this and more, through:

1. conservation of CO_2 by fixation during photosynthesis and immobilization in the biomass of standing trees
2. conservation of soils
3. improvement of degraded grassland soil morphology, physico-chemical properties, mechanical composition, clay mineralogy, and soil humus composition
4. nutrient storage and release
5. conservation of micro- and macrofauna
6. amelioration of microclimate

While no data were available on the role of *Acacia* plantations in water conservation, it should not be surmised that *Acacia* plantations play no role in this.

Among all these roles in which *Acacia* plantations can assist, the conservation of CO_2 can be considered the most important because it has global implications. *Acacia* plantations can help remove this greenhouse gas from the atmosphere and thus reduce air pollution. The other roles, also important, are felt more at the national or local (microsite) levels. Possible harmful effects of *Acacia* plantations on other crops, through production of allelophatic compounds, have been reported.

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Diseases of Acacias: An Overview

Lee Su See

Introduction

Although Turnbull (1986) lists 54 species of Australian Acacias as suitable for fuelwood and agroforestry in developing countries, especially of arid and semi-arid areas, only several have been widely planted. The first meeting of the Consultative Group for Research and Development of Acacias (COGREDA) identified seven priority species for humid and sub-humid areas and eight for semi-arid areas (Kamis and Taylor 1992). Presently the most popular species planted in countries in the East Asia and Pacific region are *Acacia auriculiformis* and *Acacia mangium*.

Acacia species are popular for reforestation and rehabilitation of degraded areas, and for agroforestry. To successfully establish and manage these species we must be fully aware of their pests and diseases as well as their biology, silvicultural features, and utilization. This paper presents an overview of known diseases of acacias, discusses the more important ones, and provides general outlines for control.

Disease Descriptions

A review of the literature on acacias prompts the interesting observation that many species have not been reported to suffer from any disease. Of the 54 species listed by Turnbull (1986) as suitable for fuelwood and agroforestry, diseases were recorded for only four species and in all cases were not serious. Of the seven priority species listed by COGREDA for humid/sub-humid areas and eight for semi-arid areas (Kamis and Taylor 1992), five in each group are not known to suffer from any disease. However, Turnbull (1986) made the qualification that much of his information is from Australian observations and may not be relevant when the trees are introduced to a new environment. There is evidence that some acacias suffer only minor disease problems in their native range but are susceptible to a number of diseases—some of them potentially devastating—when introduced into foreign lands. As areas planted with acacias expand outside their native range and the existing plantations age, reports of diseases to which the species are susceptible are increasing. This is clear from the data in Table 1, where most of the disease records are recent and from acacias planted as exotics.

Table 1 lists the diseases and pathogens of acacias more widely planted in the Asia and Pacific region. Inclusion of a record in the table does not necessarily mean that the disease causes serious damage or that control is warranted. Many of these diseases, such as leaf spots and rusts, cause only minor damage and do not significantly affect the plant's growth or yield. Sometimes a disease may cause significant losses (for example, root rot) yet control may not be feasible or economically justifiable, and other species may have to be substituted.

Table 1. Diseases and pathogens of some of the more widely planted acacias in the East Asia and Pacific region.

Tree species	Type of damage	Pathogen	Country	References
Acacia spp.	Spike disease	Sandal spike virus	India	Browne (1968)
	Heart rot	*Fomes badius, F. conchatus, F. robiniae*	Widespread Australia	Browne (1968)
	Root rot	*Polyporus schweinitzii, Fomes (Rigidoporus) lignosus*	Temperate zones Widespread	Browne (1968)
	Acacia rust	*Uromyces fusisporus, U. phyllodiorum*	Australia	Browne (1968)
		Uromycladium acaciae, U. alpinum	Australia	Browne (1968)
		U. notabile	Australia, New Zealand	Browne (1968)
	Acacia gall rust	*Uromycladium tepperianum*	Australia, New Zealand, Java	Browne (1968)
A. arabica		*Hypocrea acaciae*	India	Sarbhoy et al. (1986)
		Macrophomina phaseolina	India	Sarbhoy et al. (1986)
		Phyllachora acaciae	India	Sarbhoy et al. (1986)
A. auriculiformis	Powdery mildew	*Oidium* sp.	Haiti	Josiah and Allen-Reid (1991)
			Thailand	Aniwat (1987) Kamnerdratana et al. (1987)
		Sphaerotheca sp.	Indonesia	Ibnu and Supriana (1987)
	Damping-off	*Fusarium*	Haiti	Josiah and Allen-Reid (1991)
		Rhizoctonia		
	Sooty mold	*Meliola* sp.	Malaysia	Hong (1977) Singh (1973)
	Gall rust	*Uromyces digitatus*	Papua New Guinea	Shaw (1984)
		Uromyces	Indonesia	Supriana and Natawiria (1987)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
A. auriculiformis (cont'd.)	Leaf infection	*Colletotrichum*	India	Mohanan and Sharma (1988)
	Leaf spots	*Pestalotia* sp.	Haiti	Josiah and Allen-Reid (1991)
		Cylindrocladium quinquesepatatum, Phomopsis, Exserohilum rostratum	India	Mohanan and Sharma (1988)
	Root knots	*Meliodogyne* spp.	Haiti	Josiah and Allen-Reid (1991)
		(Nematodes)	PNG	Shaw (1984)
	Root and butt rot	*Ganoderma borninense* *Phellinus noxius*	PNG	Arentz (1990)
		Ganoderma lucidum	India	Browne (1968)
	Heart rot	*Ganoderma applanatum*	India	Browne (1968)
A. baileyana	Damping-off, root rot	*Phytophthora*	New Zealand	Browne (1968)
	Acacia rust	*Uromyclindium notabile*	Australia, New Zealand	Browne (1968)
A. catechu	Powdery mildew	*Erysiphe acaciae*	India	Browne (1968)
	Powdery leaf spot	*Microstroma acaciae*	India	Browne (1968)
	Rust	*Ravenelia tandonii*	India	Browne (1968)
	MLO type disease	Mycoplasma-like organisms	India	Sen-Sarma (1984)
	Anthracnose	*Glomerella cingulata*	Japan	Hashimoto (1968)
	Root rot	*Phellinus (Polyporus) gilvus,*	India	Bakshi et al. (1976)
		Ganoderma lucidum		Dargan (1990)
	Heart rot	*Fomes fastuosus, F. senex, Ganoderma applanatum*	India	Browne (1968)
		Pseudophaeolus baudonii	Thailand	Kamnerd-ratana et al. (1987)
		Fomes badius	India	Bakshi (1957)
A. coccinna	Leaf spots	*Pseodocercospora acaciae*	India	Sarbhoy et al. (1986)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
A. confusa	Seedling gall rust	*Poliotelium hyalospora*	Hong Kong	Ivory (1991)
	Wilt	*Fusarium oxysporum*	Hawaii	Gardner (1980)
	Root rot	*Ganoderma lucidum* *G. tropicus*	Taiwan (ROC) China	Ying et al. (1976) Tan and Wang (1984)
A. cyanophylla	Anthracnose	*Collectotrichum*, *Gloeosporium*	Florida, U.S.A.	Barnard and Schroeder (1985)
A. dealbata	Coats and kills seedlings	*Polyporus laevigatus*	Australia	Browne (1968)
	Seedling root rot	*Glomerella acaciae*	Japan	Terashita (1962)
	Anthracnose	*Glomerella cingulata*	Japan	Ogawa (1970)
	Leaf spots	*Calonectria theae*	Sri Lanka	Browne (1968)
	Rust	*Uromyces phyllodionum*, *Uromycladium acaciae, U. alpinum, U. notabile*	Australia, New Zealand	Browne (1968)
	Canker	*Hypoxylon hypomiltum*, *H. rubiginosum* *Peniophora sacrata*	Australia	Browne (1968)
	Root rot	*Peniophora sacrata* *Ganoderma applanatum*	Australia Australia, New Zealand	Browne (1968)
		Calonectria kyotensis	W. Europe, Japan, USA	Peerally (1974)
	Wound parasite and decay	*Fomes endapatus* *Polyporus, Trametes tawa* *F. mastoporus*	Australia New Zealand	Browne (1968) Browne (1968)
	Heart rot	*Ganoderma australe*	Australia	Browne (1968)
A. decurrens	Canker	*Corticium salmonicolor*	Malaysia	Singh (1973)
	Gummosis	*Ceratocystis fimbriata*	Brazil	Ribeiro et al. (1988)
	Root rot	*Hypoloma janus*	Malaysia	Singh (1973)
A. holosericea	Sooty mold	*Podoxyphium*	PNG	Shaw (1984)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
Acacia koa	Rust	*Uromyces koae Endoraecium acaciae, E. hawaiiense, U. digitatus*	Hawaii, U.S.A.	Gardner (1978) Hodges (1984)
	Shoot blight	*Calonectria thea*	Hawaii, U.S.A.	Nishijima and Aragaki (1975)
	Wilt	*Fusarium oxysporum*	Hawaii, U.S.A.	Gardner (1980)
	Collar rot	*Calonectria crotolariae*	Hawaii, U.S.A.	Aragaki et al. (1972)
	Decline	*Phaeolus schweinitzii, Polyporus sulphureus, Pleurotus ostraetus, Armillaria mellea, Ganoderma* sp.	Hawaii, U.S.A.	Bega (1979)
A. koaia	Wilt	*Fusarium oxysporum*	Hawaii, U.S.A.	Gardner (1980)
A. leucophloea	Acacia tar spot	*Catacauma acaciae*	India	Browne (1968)
	Acacia gall rust	*Hapalophragmiopsis*	India	Browne (1968)
	Rust	*Hapalophragmium tandonii*	India	Browne (1968)
	Pink disease	*Corticium salmonicolor*	India	Browne (1968)
	Root and butt rot	*Ganoderma lucidum*	India	Browne (1968)
A. longifolia	Leaf spot and blight	*Cylindrocladium scoparium*	South Africa	Hagermann and Rose (1988)
A. mangium	Damping-off	*Chaetomium* sp., *Curvularia* sp., *Fusarium solani, Fusarium* sp., *Pythium* sp., *Phytophthora* sp., *Rhizoctonia solani*	Malaysia	Khamis (1982), Lee (1985), Liew (1985), Lee and Goh (1991), Norani (1987), Maziah (1990)
	Powdery mildeww	*Oidium* sp.	Hawaii, U.S.A. Malaysia Thailand Philippines	National Research Council (1983) Maziah (1990) Aniwat (1987) de Guzman et al. (1991)
	Sooty mold	*Mekiola* cfr. *acaciarum*	Malaysia	Ivory (1991)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
Acacia mangium (cont'd.)	Leaf spots	*Collectotrichum gloeosporioides*, *Glomerella cingulata*, *Lasiodiplodia theobromae*, *Fusarium* sp., *Gloeosporium* sp., *Corynespora* sp., *Hendersonula* sp. *Pestaliopsis* sp., *Phomopsis* sp., *Phyllostictina* sp.	Malaysia	Norani (1987), Lee and Goh (1991); Maziah (unpublished data)
		Collectotrichum, *Phoma sorghina*, *Cylindrocladium quinqueseptatum*	India	Mohanan and Sharma (1988)
	Charcoal root disease	*Macrophomina* sp.	Malaysia	Khamis (1982)
	Root knot	*Meliodogyne* spp.(nematodes)	Malaysia	Chin (1986)
	Root rot	*Ganoderma* sp.	PNG	Arentz (1990)
		Ganoderma sp.	Malaysia	Lee (unpublished data)
		Rigidoporus lignosus	Malaysia	Maziah (unpublished data)
		Phellinus sp.	Malaysia	Khamis (1982), Maziah (unpublished data)
		Rigidoporus vinctus	Solomon Islands	Ivory (1991)
	Pink disease	*Corticium salmonicolor*	Malaysia	Lee (1985), Chin 1990)
	Canker	*Rhytidhysterium rufulum*	Malaysia	Ivory (1991)
	Heart rot	*Phellinus* sp. and numerous unidentified hymenomycetes	Malaysia	Lee and Maziah (1992)
A. mearnsii	Damping-off,root rot, dieback	*Cylindrocladium scoparium*	Widespread	Browne (1968)
	Leaf spots	*Calonectria theae*	India	Browne (1968)
	Acacia rust	*Uromycladium acaciae*	Australia, New Zealand	Browne (1968)
		U. alpinum	South Africa	Morris et al. (1988)
		Uromyces phyllodiorum	New Zealand	Dingley (1977)
	Acacia gall rust	*U. notabile*, *U. tepperianum*	Australia, New Zealand	Browne (1968)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
A. mearnsii (cont'd.)	Gummosis	Unknown (physiological)	South Africa	Turnbull (1986)
	Stem canker	*Dothiorella pithyophila*	India	Panneerselvan et al. (1975)
	Pink disease	*Corticium salmonicolor*	Malaysia, Mauritius	Browne (1968)
	Dieback	*Phoma herbarum*	Kenya	Olembo (1972)
	Cankers, leaf blight, root rot	*Physalospora abdita*	Australia, India, N. America, China, S. Africa	Browne (1968)
	Root rot	*Armillaria mellea*	Sri Lanka, Malawi, Tanzania	Browne (1968)
		Macrophomina phaseoli	Sri Lanka	
		Irpex subvinosus, Poria albobrunnea	Sri Lanka	
	Black butt	*Phytophthora nicotianae* var. *parasitica*	South Africa	Zeijlemaker and Margot (1971)
	Sap rot	*Schizophyllum commune*	Widespread	Browne (1968)
	Heart rot	*Stereum ostrea*	Tanzania	Browne (1968)
		Ganoderma applanatum	Australia, Sri Lanka	
A. melanoxylon	Seedling root rot	*Fusarium coeruleum*	India	Browne (1968)
		Fusarium oxysporum	India	Sarbhoy et al. (1986)
	Coats and kills seedlings	*Polyporus laevigatus*	Australia	Browne (1968)
	Leaf spots	*Calonectria theae*	Sri Lanka	Browne (1968)
	Leaf infection	*Collectotrichum*	India	Mohanan and Sharma (1988)
	Parasitic on weak saplings	*Peniophora incarnata*	Australia	Browne (1968)
	Blackwood rust	*Uromycladium robinsoni*	Australia, New Zealand	Browne (1968)
	Wilt and dieback	*Gibberella*	Australia	Browne (1968)
	Shoot dieback	*Fusarium semitectum*	India	Mohanan and Sharma (1988)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
A. melanoxylon (cont'd.)	Collar rot	*Armillaria mellea*	Australia	Purnell (1959)
	Root and butt rot	*Ganoderma lucidum*	India	Browne (1968)
		Poria vincta var. *cinerea*	East Africa	Setliff and Mesner (1971)
	Heart rot	*Stereum sanguinolentum*, *Ganoderma applanatum*	Australia	Browne (1968)
A. modesta	Rust	*Ravenelia taslimii*	India, Pakistan	Browne (1968)
	Root and butt rot	*Ganoderma lucidum*	India	Browne (1968)
	Heart rot	*Ganoderma applanatum*,	Pakistan	Browne (1968)
		Fomes fastuosus	Widespread	
		Phellinus badius, *G. applanatum*, *Ravenelia taslimii*	Pakistan	Quraishi and Ahmad (1973)
A. mollissima	Wound parasite	*Schizophyllum commune*	South Africa	Ledeboer (1946)
A. nilotica	Leaf spots	*Septogloeum acaciae*	India, Pakistan	Browne (1968)
	Leaf blight	*Septoria mortolensis*	India	Browne (1968)
	Rust	*Ravenelia acaciae-arabicae*	India	Browne (1968)
	Canker	*Hypoxylon acaciae*	India	Dargan (1990)
	Root rot	*Fomes badius*,	Widespread	Browne (1968)
		Ganoderma lucidum	India, Pakistan	
		Fomes papianus		Fagg (1992)
	Heart rot	*Ganoderma applanatum*	India	Browne (1968)
		Formes badius, *F. faxtuosus*, *F. rimosus*	India	Dargan (1990)
A. pinnata	Dieback	*Diatrype acaciae*	India	Sarbhoy et al. (1986)
	Twig blight	*Tryblidiella rufula*	India	Sarbhoy et al. (1986)
	Cankers	*Diatrype acaciae*, *Nectria coccinea*	India	Sarbhoy et al. (1986)
	Rust	*Ravenelia acaciae-pinnatae*	India	Sarbhoy et al. (1986)
		Hermatomyces tucumanensis	India	Sarbhoy et al. (1986)

Table 1, continued.

Tree species	Type of damage	Pathogen	Country	References
A. podalyriifolia	Sooty mold	Not mentioned	Australia	Turnbull (1986)
A. pycnantha	Acacia gall rust	*Uromycladium tepperianum*	Australia, New Zealand	Browne (1968)
	Golden wattle rust	*Uromycladium simplex*	Australia New Zealand	Browne (1968) Laundon and McCully (1978)
	Leaf lesions	*Monochaetia lutea, Seimatosporium arbuti*	Australia	Swart and Griffiths (1974)
	Root rot	*Armillaria mellea* *Cylindrocladium scoparium*	Australia Australia	Browne (1968) Bertus (1976)
	Heart rot	*Ganoderma applanatum*	Australia	Browne (1968)
A. salicina	Acacia rust	*Uromyces fusisporus*	Australia	Browne (1968)
A. saligna	Acacia gall rust	*Uromycladium tepperianum*	Australia South Africa	Crompton (1992) Morris (1987)

Several diseases known to cause significant damage to acacias are discussed below.

Powdery Mildew - *Oidium* state of *Erysiphe acaciae*

The fungus, an obligate parasite, causes powdery mildew on leaves of several species of *Acacia* (Table 1). Heavy infestation results in defoliation and retarded growth. Browne (1968) stated that the disease was uncommon and unimportant. However, in 1985 90-100% of *A. mangium* seedlings in the Sakaerat Project area in Thailand were heavily damaged by powdery mildew, with 75% mortality (Aniwat 1987).

Effective control can be achieved by use of fungicidal sprays and sulphur dusting.

Acacia Gall Rust - *Uromycladium notabile*

This fungus is an obligate parasite found in Australia, Tasmania, New Zealand, and South Africa (Table 1) and causes the formation of large, distorted, yellowish brown to chocolate brown swellings on leaves, stem, branches, and pods. While the pathogen is of only minor importance in mainland Australia, it is destructive in Tasmania, and in New Zealand, it has caused the failure of *Acacia mearnsii* plantations and considerably depreciated the value of other *Acacia* spp. as plantation crops (Browne 1968).

However, this disease has not seriously affected acacia plantations elsewhere. Effective control of rust diseases requires an understanding of the life cycle of the pathogen. Use of resistant host species is a long-term strategy for effective disease control.

Root Rot -*Ganoderma* spp. and *Phellinus* spp.

Root rot, usually caused by soil-borne facultative parasites, is a common disease of many acacias. *Ganoderma* and *Phellinus* are two of the main root rot fungi (Table 1).

In Papua New Guinea survival of *A. auriculiformis* planted on cleared rainforest sites in the Gogol Valley has been poor: 40% of the trees died by age eight, most killed by root rot caused by *Phellinus noxius* or *Ganoderma borninense* (Arentz 1990). *A. mangium* trees in Papua New Guinea have also been found to suffer from root and butt rot caused by a *Ganoderma* sp. (Arentz 1990). This has cast doubt on the suitability of these species for reforestation of lowland rainforest sites in Papua New Guinea. *Ganoderma* sp. has also been found as the main root rot pathogen in *A. mangium* plantations in Peninsular Malaysia. Studies are underway to determine the incidence and spread of the disease.

Control of root diseases spread by root contact usually involves the removal of all diseased roots and other woody debris that may harbor the pathogen. Alternatively, sites with a lot of woody debris (stumps, etc.) or known to have a history of root diseases should be avoided. This may not be practical for acacia plantations. If it is confirmed that acacias are very susceptible to root and butt rot, the only feasible methods of control would be the use of varieties with a high degree of resistance to the pathogens, or to plant other species.

Heart Rot - *Phellinus* sp. and various wood decay hymenomycetes

Although a common disease of many acacias (Table 1), heart rot was not considered a serious disease until recent reports of its high incidence in *A. mangium*.

Heart rot in *A. mangium* was first reported in 1981 from Sabah (Gibson 1981) and has since been found in plantations in Sabah, Peninsular Malaysia, and Indonesia. In Sabah, an average of 35.5% of 6- to 9-year-old trees surveyed had heart rot (Mahmud, Lee and Ahmad 1992); in Peninsular Malaysia, between 49.2% to 97.3% of 2- to 8-year-old trees had heart rot (Tang and Zulkifli 1992). Volume loss figures were however considerably lower. The study in Sabah reported a loss of between 0.03% and 18.0% of the heartwood of the whole tree. In Peninsular Malaysia volume loss from the entire tree ranged from 0.7-3.0%, and from the first 6-m log ranged from 0.8-9.8%. Sawn timber recovery of between 42.8% and 49.9% has been reported from Peninsular Malaysia (Tang and Zulkifli 1992). No figures are available from Indonesia.

A variety of fungi are associated with heart rot in acacias (Table 1). *Phellinus* and several other wood decay hymenomycetes have been isolated from heart rotted *A. mangium* trees in Peninsular Malaysia (Lee and Maziah, in press). Studies by Lee et al. (1988) and Ito (1991) established that discoloration and heart rot in *A. mangium* trees were associated with fungal invasion of poorly healed wounds, especially those left by branch stubs and dead branches.
This disease has serious implications on the final end-use of the timber.
Although timber with heart rot can still

be used for chips and composite products without appreciable loss in quality, it would not be suitable for use as structural timber. Presently there is no practical method of control for this disease.

Prevention and Control Strategies

Disease-free planting material is of paramount importance in ensuring that no new diseases are introduced with the exotic species to be planted in a new area. Thus the importance of quarantine and phytosanitary measures cannot be over emphasized, especially if planting material (such as seeds) has to be imported.

It is, however, reassuring to note that presently most new pathogens of exotic acacias are generally locally known pathogens that have adapted to a new host. However, the impact of these local pathogens on the exotic hosts may not be immediately apparent. Thus **constant surveillance and early detection** are essential to effectively prevent and control diseases in plantations. This may be achieved through inclusion of pest and disease monitoring during species and provenance trials, and through systematic surveys in nurseries and all stages of plant development. Foresters trained to recognize disease symptoms and signs are in the best position to conduct such regular surveys. This early warning system can then alert researchers to potential problems requiring further investigative studies.

Site preparation has an important impact on disease incidence and spread. For example, woody debris and stumps left after felling and land clearing are usually inoculum sources for root and but rot pathogens. Due to the facultative saprophytic nature of such fungi, the presence of such woody material in the plantation makes the control of root and butt rot very difficult if not impossible.

Silvicultural practices also have an important impact on disease incidence and spread. For example, in *A. mangium*, large and slow-healing wounds left after singling and pruning often act as infection courts for heart rot fungi. On the other hand, well planned and careful thinning can reduce the inoculum potential of many diseases in the plantation.

Planting patterns also have a role in disease control. It is well known that diseases spread much more rapidly in monoculture, even-aged plantations. By using mixed block plantings, the spread of disease may be checked. However, trials are needed to determine the best species mix and optimum block size for optimum yield and effective pest and disease control.

Coordinated research and exchange of information between researchers in the region would serve to update information on the current pest and disease situation in each country and also to alert fellow researchers of potential problems.

Conclusion

Presently very few researchers are actively studying diseases and fungi of tropical forest plantation species, and even fewer are studying those of tropical forest trees. To make the work of these few more effective, there should be closer linkages and better communication between them for increased exchange of ideas, research techniques, and findings of mutual interest.

Through vigilant surveillance, early detection, and information exchange the pitfalls of large-scale planting of disease-susceptible species may be avoided, and outbreaks of serious diseases may be effectively controlled or prevented. Such information is increasingly important in view of the widespread and growing interest in planting acacias and other exotics in developing countries.

Discussion Notes

Other diseases include gall disease on stems of seedlings due to bacteria, and pink disease. The former has destroyed 70,000 seedligs of *A. mangium* in Peninsular Malaysia.

Q: It seems that a potentially serious pest is the pin-hole borer on *A. crassicarpa* in Sabah. Has it been found elsewhere?

A: It has also been found in Peninsular Malaysia; the scoratid beetle carries the fungus. Probably both contribute to the damage. Ahmad Said Sajap has prepared an article on this topic, now in press with *Malaysian Forester.*

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Choosing Acacias for Rural, Industrial, and Environmental Development

Sompetch Mungkorndin

Introduction

A short definition of economics by Samuelson (1976) sets the scope of this paper: "How do we choose to use scarce productive resources with alternative uses, to better meet prescribed ends - what goods to produce, how, and for whom, now or later?" For economics of acacias, these definitional questions are modified to cover what species to choose from? Using what criteria? For what purposes and what are prospects in the future?

Other papers in this volume present various acacias, with their specific uses. An economic perspective can identify criteria to choose among all these species in a given set of conditions. Because rural, industrial and environmental developments usually have distinct, with more or less overlapping, goals, discussions will be categorized for each type of development.

Acacias for Rural Development

The primary goals of rural development are often to raise income and employment while at the same time uplift the welfare of rural people. These primary goals imply others related to environmental protection and increased agricultural productivity.

Income and Employment

Tree products from acacias can help generate income and employment. Important products are listed here with probable utilization, criteria for selection and examples of species.

Poles and Posts

Acacias are not well known for their use as poles and posts, unlike casuarinas or eucalypts. Using the criteria of fast growth, length, straightness, and clear bole, strength, and durability, *A. auriculiformis* can be used as a short pole, provided that improved genetic sources are used. The hybrid of *A. auriculiformis* and *A. mangium*, with its straight and long stems, may be a better option. *A. nilotica* is used as pit props and mining planks in Pakistan (Sheikh 1989).

Timber

Construction timber tends to play a subordinate role in rural development, but it can generate income from tree farms and homestead plantings. Species for construction should have, besides fast growth, strength, hardness, toughness, and ease of wood working. Growth performance is determined by mean annual increment (mai) but broad comparisons are not feasible. Growth figures for acacias are quite scattered and site specific (Table 1).

Table 1. Mean annual increments of selected acacias

Species	MAI (m^3/ha/yr)	Source
A. auriculiformis	8-10	Busby (1985), India
	23	Mangundikoro (1986), Indonesia
	17-20	Chuan and Tangua (1991), Sabah
A. mangium	27-44	NRC (1983), Sabah Softwoods
	10-29	Chuan and Tangau (1991), experiences from SAFODA
A. nilotica		Sheikh (1989), Pakistan
Site Quality I age 20	13.0	
Site Quality II age 20	7.1	
Site Quality I age 30	10.5	
Site Quality II age 30	6.2	
A. tortilis	10-12	Busby (1985), India

For rural development, decision making of small farmers may be based on net returns regardless of time. However, determining returns for more intensive farm operations requires good records of cashflows with proper discount factors for accurate criteria of net present value, benefit/cost ratios and internal rate of returns. (See the discussion of industrial plantations below.)

Food

Traditionally, Aboriginal people in central Australia used at least 49 species of acacias (Devitt 1992), examples start from *A. acradenia* to *A. victoriae*. For the most part, however, introduced acacias have not been exploited as food sources.

Young leaves of *A. pennata* ssp. *insuavis* are consumed as vegetables in the countries of Indochina where it is native: Thailand, Myanmar (Burma), Laos, and Cambodia. This shrub has been domesticated and, with selection for taste and thornlessness, is becoming an agronomic crop in these areas. *Acacia albida* (*Faidherbia albida)* is another example of a food-producing acacia: the seeds contain up to 27% crude protein and are eaten by people of Zimbabwe during times of famine (National Academy of Sciences 1975; Marunda 1992).

Criteria for selection of acacias for food are modified after Harwood (1992), as follows:

- low level of toxins
- easy establishment, fast growth and heavy food-production
- ease of food collection and processing using local technology

- other beneficial effects for the local farming system (windbreaks, soil amelioration)

- ease of production and marketing

Fuelwood

The marketability of fuelwood varies widely. In some places, fuelwood can substitute for dung and crop residues, which can instead be applied to fields for greater soil fertility and crop production. Where there is a fuelwood market, the crop can be sold to provide income. Fuelwood should have good calorific value and burning patterns suitable for cooking, making charcoal, firing pottery, ceramics and lime, steaming the engines, etc. The ease of collecting, longer burn, less and favorable smokes, and local preferences are also important factors. Examples of popular acacia fuelwoods include *A. auriculiformis* in the humid tropics, *A. mearnsii* in tropical highlands, and *A. nilotica* and other species in aiid and semi-arid regions (NAS 1980; 1983). Turnbull et al. (1986) list 53 fuelwood and agroforestry Australia acacias, from *A. ammobia* to *A. xiphophylla*.

Other Products

Extractives should not be overlooked in the decision of species selection (see the paper by H.H. Chung in this volume). Gum arabic from *A. senegal* is used all over the world, with about 40,000 tons exported annually from African countries for use in foods and beverages, pharmaceutical preparations, confections, and a wide range of industrial applications. Over 100 acacias are known to exude copious amounts of gum when their bark is damaged, and at least six have gums with apparent commercial promise, including *A. auriculiformis* and *A. berlandieri* (NAS 1983).

Tannins for use in leather-making, dying, and chemical industries come from bark of acacias, especially *A. mearnsii* and from fruit pods of *A. nilotica*. At rural level, it is practical to extract tannin from chipped materials, then make a tanning liquor to use directly. Preparation of solid tanning extracts is time consuming but still practiced in some parts of India and Thailand. The tanning liquor is called cutch and solid extract called katha. (See the paper by Subansenee et al. in this volume). A few acacias such as *A. catechu* have medicinal uses.

Improved Farm Productivity

Fodder Trees

Some arid and semi-arid acacias grow under severe conditions, where they can provide shade and fodder for animals and act as living fences to keep livestock from crops. *A. albida, A. nilotica, A. tortilis*, and others are used in this way. Criteria for fodder trees are (modified from FAO 1978):

1. easy establishment and maintenance in the selected environment

2. palatability and non-toxicity to animals

3. nutritive value

4. production and growth (related to drought-resistance and quick recovery from browsing)

Soil Conservation and Environmental Protection

Because they are generally hardy, acacias have potential for use as windbreaks and shelterbelts. They are nitrogen-fixing trees that can improve the fertility of wastelands and conserve the soil on steep slopes. While these functions will often be secondary to other products in the decision of species choice, here we may note the simple criteria that the species should be hardy and suitable for the specific purpose of conservation and protection required by the site, and not pose the threat of becoming 'weeds'.

Acacias for Industrial Development

Industrial development aims at economic growth, and while each business firm involved in industrial forestry aims to maximize profits, the aims of social welfare and environmental sustainability are complementary to this primary goal in the long term. Industrial forestry is usually capital intensive.

As for other purposes, selection of species for industrial development depends on the grower's objectives and site constraints. With advances in utilization technology and the multiple products obtainable from acacias, various combinations of integrated production of lumber, pulp, paper and composite products are now possible. To date, *A. mangium* is the most widely used acacia in industrial forestry, but with greater knowledge of other species this may change. Criteria for selection of industrial acacias may be generalized as suitability to:

1. site conditions
2. available markets and market projections
3. available processing technology
4. silvicultural management
5. corporate/owner objectives (e.g., high yields and financial returns)

In industrial decisions, the financial internal rate of return (IRR) is usually employed. Given the short history of experience with *A. mangium*, these figures still vary widely. For example, a financial analysis of an *A. mangium* plantation of the Sabah Forestry Development Authority (SAFODA) indicated an IRR of 16.2% (all social and infrastructure components included) given an mai of 24.4 m^3/ha/yr on a 12-year rotation (Chuan and Tangau 1991). When Chuan and Tangau (1991) calculated indicative returns of forest plantation investment in mixed plantation of *A. mangium* and *Gmelina arborea*, however, expected IRR was only 5.9% (13.1% with optimistic assumptions) and considered unimpressive without further government investment incentives. An analysis of *A. mangium* plantation by Sabah Softwoods Sdn Bhd (SSSB) on a pulplog regime of eight years with an assumed mai of 25 m^3/ha/yr gave an IRR of only 4.5%.

On the other hand, *A. mangium* plantation for electric posts in the Philippines, with an apparently assured market, gives very attractive IRR values (Francisco 1993). A financial analysis of the Compensatory Forest Plantation Project (CFPP) in Peninsular Malaysia, where 80% of the planting area is *A. mangium*, showed an IRR of 19.4%, and when benefits to society at large were included, the economic IRR rose to 28.8% (Mahmud and Sirin 1991).

Acacias for Environmental Development

Besides ameliorating energy crises with the renewable energy of fuelwood (and charcoal), acacias can help reduce other environmental crises as well. In soil conservation and landscaping, *A. auriculiformis* is well known. Like some other acacias, it is used for land reclamation (e.g., former tin-mining sites), protection, and stabilization. Because environmental conservation and development is a formidable task, criteria for development must be cost-effectiveness rather than optimization of profit. Economic considerations in selecting acacias for this purpose are:

- low cost of establishment (e.g., seed and seedlings, site preparation)
- suitability to objective
- suitability to site (e.g., low maintenance and fertilizer requirements)
- non-weediness

Conclusions

This paper postulates different sets of criteria for each of the three development purposes identified in this workshop's theme. For industrial development criteria are not based on appropriate technology, labor intensive, or low input, but instead are based on optimizing profits subject to existing constraints.

Selecting species for rural and environmental development requires considerations of income, employment, and welfare of rural people. Environmental development is becoming a controversial issue in many developing countries. Acacia scientists should recognize the environmental costs and benefits of these species and use reliable assumptions on cost and benefit streams. Indicators from economic analyses can contribute realistic criteria for choosing the right species.

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Appendix 1: Recommendations from COGREDA's First Meeting, June 1-3, 1992

The first meeting of COGREDA reviewed the areas of species assessment and selection of acacias, improvement and propagation, silviculture, growth and yield research, insect pests, properties and utilization, and economics and marketing. The discussion focussed on the countries of East Asia and the Pacific.

Working groups suggested the priorities for research outlined below.

Species Assessment and Improvement

Table 1 shows the priorities for species assessment and improvement. Because the experience with acacias in East Asia and the Pacific has been primarily with humid and sub-humid species, the recommended priorities for semi-arid acacias in Table 1 should be regarded as provisional, and reflect only their relative priority in that region. In

Table 1. Priorities for species assessment and improvement.

	Provenance trials	Seed prod. area	Plus tree selection	Seed orchard	Progeny tests	Cutting propagation	Tissue culture
Humid/Sub-humid Species							
A. auriculiformis	0	2	3	2	2	0	0
A. mangium	0	2	3	3	3	0	0
A. aulacocarpa	3	2	3	1	3	3	3
A. crassicarpa	3	2	3	1	3	3	3
A. leptocarpa	1 (s)	1	1	1	1	1	1
A. oraria	1 (s)	1	1	1	1	1	1
A. cincinnata	1 (s)	1	1	1	1	1	1
A. angustissima	1 (s)	1	1	1	1	1	1
Semi-arid and Arid Species							
A. ampliceps	2 (s)	2	1	1	1	1	1
A. brassii	2 (s)	2	1	1	1	1	1
A. difficilis	2 (s)	2	1	1	1	1	1
A. holosericea	2 (s)	2	1	1	1	1	1
A. plectocarpa	2 (s)	2	1	1	1	1	1
A. catechu	2 (s)	2	1	1	1	1	1
A. arabica	2 (s)	2	1	1	1	1	1
A. confusa	2 (s)	2	1	1	1	1	1

Priority ranking: 0 = done, 1 = low, 2 = medium, 3 = high. (s) indicates that silvicultural research shoul these species before improvement work begins.

other regions, these or other acacias may receive different priority rankings.

Specific suggestions were also made regarding further research on promising acacia hybrids.

Silviculture

Recognizing that different growing conditions and objectives dictate different research needs, Table 2 describes silvicultural priorities for site rehabilitation, industrial plantation, and agroforestry.

For rehabilitation planting, grasslands recovery is a regional priority. In industrial plantations, silvicultural practices depend on the product; therefore this portion of the table is divided between pulp, fuelwood, and chemical uses on the one hand, and sawn timber on the other.

Conditions of pest and disease control vary from country to country. Periodic surveys of pests and diseases, with damage assessments, should identify the significant problems in an area. From this determination, appropriate integrated pest management (IPM) practices can be developed, depending also on the crops grown in association with the trees.

The heart rot affecting *A. mangium* is not addressed in Table 2 for several reasons, including the fact that, except by selecting alternative species, there are few means for tackling the problem.

From the point of commercial-scale management, the most important consideration is to reduce weeding costs (which now accounts for up to 70% of establishment costs) and examine soil preparation. Reducing the length of time seedlings spend in the nursery is relatively insignificant in terms of cost.

Silvicultural practices for hybrids is an area considered to be automatically included in the areas identified for other silvicultural research.

Utilization, Economics and Marketing

Table 3 shows a priority ranking for utilization research, by species and product. A priority ranking of general research areas in this field, using the same scale as in the tables, appears below.

Topic	Rank
Development and utilization of non-wood products	2
Utilization of small-size logs (grown in plantation and by farmers)	2
Development of local processing technology(including products for community consumption)	3
Appropriate machinery development (harvesting saw logs, peeling, chipping, defibrating)	3
Basic research on solid wood and fiber/ particle characteristics of recently introduced materials	3

For Economics and Marketing studies, the following topics are of primary importance (not prioritized):

- cost-benefit analysis of products intended for introduction, and under different planting systems

- economics of introducing appropriate machinery for processing small-diameter trees
- processing economics for small-sized trees
- transportation (freight)
- storability of wood materials
- processing incentives
- creation of processing centers (local industry centers)
- exchange rate changes and their effect on marketing produce of large-scale plantations
- assessment of acceptance and market for new products
- supply and demand of acacias in the wood industry
- ergonomic factors in harvesting and processing
- government policy incentives, including tax credits
- cost-effectiveness studies

Table 2. Priorities for silvicultural research for three sets of objectives, by species.*

Site Rehabilitation

Species	Sp.-Site Suitabl.	Gr.& Yld	Ds	Plant. Estab. Sp	T	Pr	Pl	Th	FA	RM	PD
Humid/Subhumid											
A. auriculiformis	1	3	3	2	2	1	1	0	0	1	2
A. mangium	1	3	3	1	1	1	1	1	C	1	2
A. aulacocarpa	3	1	1	2	2	2	2	0	0	2	1
A. crassicarpa	3	1	1	2	2	2	2	0	0	2	1
A. leptocarpa	3	1	1	2	2	2	2	0	0	2	1
A. oraria	3	1	1	2	2	2	2	0	0	2	1
A. cincinnata	3	1	1	2	2	2	2	0	0	2	1
A. angustissima	3	0	0	0	0	0	0	0	0	2	1
Semi-arid											
A. arabica	2	2	1	2	2	2	2	3	2	2	3
A. uechu	3	3	1	2	2	1	2	3	2	2	3
A. confusa	2	3	1	2	2	2	2	3	2	2	3
A. nilotica	3	3	1	2	2	2	2	3	2	2	3
A. pennata	2	3	1	2	2	1	2	3	2	2	3

Industrial Plantation — Pulp, Fuelwood, and Chemical Uses

Species	Sp.-Site Suitabl.	Gr.& Yld	Ds	Plant. Estab. Sp	T	Pr	FA	RM	PD
Humid/Subhumid									
A. auriculiformis	0	3	3	1	1	0	2	1	2
A. mangium	0	3	3	1	1	0	2	1	2
A. aulacocarpa	3	1	1	1	1	0	2	2	1
A. crassicarpa	3	1	1	1	1	0	2	2	1
A. leptocarpa	3	1	1	1	1	0	2	2	1
A. oraria	3	1	1	1	1	0	2	2	1
A. cincinnata	3	1	1	1	1	0	2	2	1
A. angustissima	3	0	0	0	0	0	0	2	1
Semi-arid									
A. arabica	2	1	2	2	2	3	2	2	3
A. uechu	3	1	2	2	1	3	2	2	3
A. confusa	2	1	2	2	2	3	2	2	3
A. nilotica	2	1	2	2	2	3	2	2	3
A. pennata	2	1	2	2	1	3	2	2	3

Industrial Plantation — Sawn Timber

Species	Sp.-Site Suitabl.	Gr.& Yld	Plant. Estab. Ds	Sp	T	Pr	Th	FA	RM	PD
Humid/Subhumid										
A. auriculiformis	0	3	3	3	3	3	3	3	2	1
A. mangium	0	3	3	3	3	3	3	3	2	1
A. aulacocarpa	3	3	1	3	3	3	3	3	1	2
A. crassicarpa	3	3	1	3	3	3	3	3	1	2
A. leptocarpa	3	1	1	1	1	1	1	1	1	2
A. oraria	2	1	1	1	1	1	1	1	1	2
A. cincinnata	2	1	1	1	1	1	1	1	1	2
A. angustissima	0	0	0	0	0	0	0	0	1	2
Semi-arid										
A. arabica	1	1	1	1	1	1	1	1	1	1
A. uechu	1	1	1	1	1	1	1	1	1	1
A. confusa	1	1	1	1	1	1	1	1	1	1
A. nilotica	1	1	1	1	1	1	1	1	1	1
A. pennata	1	1	1	1	1	1	1	1	1	1

Agro- and Community Forestry

Species	Sp.-Site Suitabl.	Gr.& Yld	Plant. Estab. Sp	Pr	Pl	RM	PD
Humid/Subhumid							
A. auriculiformis	0	1	3	2	3	1	2
A. mangium	0	1	3	2	3	1	2
A. aulacocarpa	3	3	3	2	3	2	1
A. crassicarpa	3	3	3	2	3	2	1
A. leptocarpa	3	3	3	2	3	2	1
A. oraria	2	2	3	2	3	2	1
A. cincinnata	2	2	3	2	3	2	1
A. angustissima	3	1	0	0	0	2	1
Semi-arid							
A. arabica	2	3	2	2	3	1	1
A. uechu	3	2	2	2	3	1	1
A. confusa	2	2	2	2	3	1	1
A. nilotica	2	2	2	2	3	1	1
A. pennata	2	2	2	2	3	1	1

Sp.-Site Suitabl. = Species-Site Suitability; Gr.& Yld. = Growth and Yield; Ds = Direct seeding; Sp = Spacing; T = Tending, Pr = Pruning; Pl = Pollarding; Th = Thinning; FA = Fertilizer Application; RM = Rhizobia and Mycorrhizal Relationships; PD = Pests and Diseases. Priority rating: 0 = no work needed; 1 = low priority; 2 = medium priority; 3 = high priority.

*For PD, numbers indicate priority for periodic survey of pests and diseases, excepting heart rot of *A. mangium*, which receives the highest priority (3).

Table 3. Priorities for utilization research, by species and product.

	Timber C	Timber Sc	Timber Nc	Part.	Chips Fiber	Food	Fuel	Bark	Ven./Plwd	Slcg	LVL	Glue, Lam.	Hny.	Fod.	Chem.	Envir. Plant.	Posts	Crft.	Countries	Comments
Humid/Subhumid																				
A. mangium	2	2	2	3	3	0	2	2	3	3	3	3	3	2	2	3	1	3	All	General utility timber
A. auriculiformis	2	3	3	2	2	0	3	2	2	3	3	3	3	2	2	3	2	3	All	High silica content, poor form
A. aulacocarpa	2	2	2	2	2	0	2	2	2	3	3	3	3	1	1	3	2	3	Recently introduced	Good sawn wood
A. crassicarpa	2	2	2	2	2	0	2	2	2	3	3	3	3	1	2	3	2	3	Recently introduced	Furniture
A. leptocarpa	1	2	2	2	2	0	2	2	2	3	3	3	3	2	3	3	2	1	Recently introduced	Good sawn wood
A. oraria	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	3	2	2	Recently introduced	
A. cincinnata	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	3	2	3	Recently introduced	
A. angustissima	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	3	2	2	Recently introduced	
Semi-arid																				
A. arabica	1	1	2	1	1	1	3	2	1	1	1	2	3	2	3	3	2	1	Pakistan, India, Nepal	Gum, fuel uses
A. catechu	1	1	2	1	1	1	3	3	1	1	1	3	3	2	3	3	2	1	Bn, In, L, My, N, Th, V	Poor form, fire-tolerant
A. confusa	1	1	2	1	1	0	3	2	1	1	1	2	3	1	0	1	2	2	Ph, ROC, Th	Slow growing
A. nilotica	1	1	2	1	1	0	3	2	1	1	1	2	3	2	3	3	2	1	SE Asia, In, Pak	General utility in dry areas
A. pennata	1	0	0	0	0	3	0	0	0	0	0	0	0	2	2	3	0	0	L, Ca, Th	Shrub

C = Construction; Sc = Semi-construction; Nc = Non-construction; Part = Particleboard; Ven/Plwd = Veneer/Plywood; Slcg = Slicing; LVL = Laminated veneer lumber; Lam. = Laminating; Hny = Honey; Fod = Fodder; Chem = Chemical; Envir Plant = Environmental Planting; Crft = Handicrafts.

Countries: Bn = Bangladesh, In = India, L = Laos, My = Myanmar (Burma), N = Nepal, Pak = Pakistan, Ph = Philippines, ROC = Republic of China (Taiwan), Th = Thailand, V = Vietnam.

Priority rating: 0 = done or not needed; 1 = low priority; 2 = medium priority; 3 = high priority.

Appendix 2: Field Visit Summary

The Ban Phu National Park near Sakhon Nakhon, in northeastern Thailand, and the resettlement program there managed by the regional office of the Royal Forest Department (RFD) illustrate the immediate importance of the themes explored in the Udorn Thani meeting.

The area receives less than 1,500 mm annual rainfall, with average temperatures ranging from 5°C to a maximum in recent years of 38°C. The area's uplands were originally dipterocarp forest; the lowlands dry evergreen forest. Cash crop agriculture, logging, and population pressure have all but eliminated the forest area.

In 1981, under the direction of the Thai royal family, RFD began to resettle communities living in the park reserve to the lowlands near the nearby reservoir. This program relocated 11 villages, a total of 1,500 families, providing each family with up to a maximum of 15 rai (6.25 rai = 1 ha), tree seedlings (including *A. mangium* and *A. auriculiformis* for fuelwood and charcoal), and technical guidance. The program also provided health centers and schools through other government agencies. Resettlement schemes elsewhere in Thailand have been under attack in the media for their lack of clarity over land rights issues and concern for villagers' rights to land recently declared forest reserve, as well as the impression that they favor interests of industrial plantations.

The controversy surrounding such resettlement schemes in other provinces of Thailand is apparently absent here, but the national conflict is not yet resolved between park demarcation and conservation on the one hand and, on the other hand, communities' traditional use of land, which in many cases preceded establishment of parks.

Crops grown by farmers in the new "forest villages" near Nakhon Sakhon include kapok (*Ceiba pentandra*), tamarind, and cassava. Near their homes many have planted papaya and other homegarden species. Other crops include *Dendrocalamus* spp. (bamboo), gallangall (*kha* in Thai), a root crop used in Thai cooking.

The farmers' new land is marginally agricultural, but in hard circumstances tree crops, including acacias, help farm households make their new homes livable and profitable. Trees grown include *Azadirachtia indica*, whose inflorescences are sold in local markets for food, and *Acacia insuavis* , which serves as a living hedge and produces marketable leaves used in Thai soups.

Plate 1. Dr. H.H. Chung inspects charcoal-making kiln near roadside planting of *A. auriculiformis.*

Plate 2. A leading tree farmer, *Luung* Jaawn, and his daughter.

Eucalypts and *Acacia mangium* planted along the road by RFD are used to make charcoal in kilns (Plate 1).

One innovative farmer, *Luung* Jaawn, has his own seedling nursery (Slide 3) and seedlings of *Spondias* sp., as well as other species. He and his family, including their four-year-old daughter, have, after four years on their settlement farm of 14 ha, begun to receive income from sale of their banana and papaya produce (Slide 8).

In the buffer zone at the edge of the park, RFD has planted fast-growing plantation species, including *A. mangium* and *A. auriculiformis.* Buffer-zone management is a critical issue in Thailand, and points up the need for clear land tenure policy for both industrial and rural development, as well as for environmental stabilization.

Many thanks to Mr. Prayuth Saipankaew, Chief, Community Forestry Program, Regional Forest Office, Udorn Thani, for organizing the visit.

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