New Forest **28:** 207–215, 2004.

Gmelina arborea – a viable species for smallholder tree farming in Indonesia?

JAMES M. ROSHETKO[1,*], MULAWARMAN[2]
and PRATIKNYO PURNOMOSIDHI[3]
[1]*Winrock International and the International Centre for Research in Agroforestry (ICRAF), Jl. CIFOR, Situ Gede, Sindang Barang, P.O. Box 161, Bogor 16001, Indonesia;* [2]*World Agroforestry centre, ICRAF, Southeast Asia Regional Office, International centre for Research in Agroforestry, Jl. CIFOR, Situ Gede, Sindang Barang, P.O. Box 161, Bogor 16001, Indonesia;* [3]*ICRAF, Kotabumi, Lampung, Indonesia; *Author for correspondence (e-mail: J.Roshetko@cgiar.org)*

Received 5 April 2003; accepted in revised form 10 December 2003

Key words: Agroforestry, Farmer trials, Land rehabilitation, Smallholder timber production, Species selection

Abstract. Across Indonesia there are millions of hectares of degraded land in need of rehabilitation. There is interest at both the government and farmer level of converting some of these lands to more productive use, including growing trees. Smallholders often practice tree farming to generate income and traditionally cultivate a wide range of tree species in mixed agroforestry systems. Grown to satisfy both household needs and market demand, smallholder-produced timber might play a potentially important role in local markets. *Tectona grandis, Swietenia macrophylla,* and *Paraserianthes falcataria* are common smallholder timber species. *Gmelina arborea* (gmelina) is easy to cultivate and grow at the smallholder level. It has been widely grown in plantations in South and Southeast Asia, including Indonesia. However, gmelina is not yet a priority species with Indonesian smallholder farmers. Experience indicates that marketable small-diameter gmelina timbers can be produced in 7–10 years and that price compares well with that of *Paraserianthes,* the most widely grown short-rotation smallholder timber species in Indonesia. Most gmelina seed originates in Central Java, from where large quantities of seed are shipped annually to other parts of Indonesia. This seed is of uncertain quality, as seed sources are unidentified and seed collection guidelines are not used. It is recommended to establish smallholder plantations with seed of known quality. Gmelina holds promise as one component for a multi-species smallholder tree farming systems to produce short-rotation timbers for household use and local markets.

Palabras clave: Agroforestales, Ensayos agrícolas, Producción de madera por pequeños propietarios, Rehabilitación de tierras, Selección de especies

Resumen. A través de Indonesia, hay millones de hectáreas de terrenos degradados los cuales necesitan ser rehabilitados. Existe interés tanto al nivel gubernamental como al nivel de los agricultores, en convertir algunos de estos terrenos en sitios productivos, incluyendo la producción de árboles. Con frecuencia, para generar ingresos, los pequeños propietarios plantan árboles para cosecha y tradicionalmente cultivan un amplio rango de especies de árboles, en una variedad de sistemas agro-forestales. La madera de los pequeños propietarios, producida para satisfacer tanto las necesidades hogareñas como las demandas del mercado, puede jugar un papel potencialmente importante en los mercados locales. La *Tectona grandis,* la *Swietenia macrophylla,* y el *Paraserianthes falcataria* son especies comúnmente producidas por los agricultores. La *Gmelina arborea* (gmelina) es una especie de fácil cultivo y crecimiento al nivel de los pequeños propietarios, y se ha venido produciendo ampliamente en el sur, y el suroriente de Asia, incluyendo Indonesia. Sin embargo, la gmelina no es aún una especie de prioridad para los pequeños agricultores de Indonesia. La experiencia indica, que la madera de gmelina de pequeño diámetro puede salir al mercado en un período de 7–10 años y que el precio de esta madera es

comparable con la madera del *Paraserianthes*, la cual es la especie de corta rotación más ampliamente utilizada por los pequeños propietarios en Indonesia. La mayoría de la semilla de la gmelina proviene de Java Central, de donde se envían anualmente grandes cantidades de semilla a otras partes de Indonesia. Esta semilla es de calidad incierta, ya que las fuentes de semilla no están identificadas y no se utilizan normas de colección de semillas. Se recomienda que las plantaciones de los pequeños propietarios sean establecidas con semilla de calidad conocida. La gmelina es prometedora como parte del sistema de cultivo de árboles de especies múltiples de los pequeños propietarios, para producir madera de corta rotación para ser utilizada localmente y enviada a mercados locales.

Introduction

Across Indonesia there are 15.1 million hectares (4.5% of the country) of degraded land in need of rehabilitation (Ministry of Forestry 2001). There is interest at governmental and farmer levels to convert some of these lands to more productive use, including tree crops (Tomich et al. 1997; Roshetko et al. 2002). Smallholders cultivate 1–5 ha of land and often practice tree farming to generate income. They traditionally cultivate a wide range of tree species in mixed agroforestry systems, with timber included as an objective. Farmer preferences for species largely depend on household needs and markets (Yuliyanti and Roshetko 2002a). However, farmers and the non-government organizations (NGOs) that support them have little access to quality tree germplasm (Roshetko 2001), or control over the tree species made available to them. Scientists or extension services generally make the decisions – screening new species in on-station trials or from available literature and evaluating them according to biophysical criteria (Franzel et al. 1998), without considering markets. Farmer-designed trials and participatory evaluation are important means to strengthen farmers' role in species selection and technology development process for their specific biophysical and socio-economic conditions.

In July 2000, the International Centre for Research in Agroforestry (ICRAF) and Winrock International, through the support of the Danida-funded Indonesia Forest Seed Project (IFSP), initiated a project to enhance the tree planting activities of farmers and NGOs by: (i) increasing the availability and use of quality tree seed; and (ii) strengthening the technical awareness and skills of farmers and NGOs regarding tree germplasm collection and management. Activities include surveys and participatory appraisals; training courses and workshops; the distribution of quality tree seed; the production and distribution of farmer–NGO appropriate documents; and the establishment of farmer-designed demonstration trials. This paper summarizes results and observations from these activities that are relevant to the planting and utilization of *Gmelina arborea* (gmelina) by smallholder farmers in Indonesia.

Materials and methods

Geographic focus

Any NGO and farmer group in Indonesia is eligible to participate in project surveys, receive supplies of quality tree seed, and receive project documents. Field

activities are focused in Nusa Tenggara, Lampung and Central Java where ICRAF, Winrock and the Danish Embassy had strong pre-existing linkages with local NGOs and farmer groups.

Surveys

A pre-project survey was distributed to 120 NGOs and similar organizations to: (i) review the project design; and (ii) identify partners' priority species, germplasm pathways, capacities and needs. Later the project conducted a survey of the 140 known tree seed suppliers in Indonesia to determine: the species for which seed is available, the source and quality of this seed, and the agents and dynamics of the formal tree seed sector. Additional field surveys and appraisals have been conducted during the implementation of the project.

Farmer demonstration trials

Farmer demonstration trials (FDTs) are a key component of the project. Farmers select the species to be included in the trials. The project staff help farmers and NGOs conceptualize and design the trials for their specific biophysical and socioeconomic conditions. Farmers are responsible for managing the trials, with advice from project or NGO staff. The project provides practical guidelines for trial evaluation. This type of trial is an effective means to identify farmers' species preferences and tree management skills, develop farmer innovation, and assess species performance under farmers' conditions (Franzel et al. 1998). Because randomization, replication and management may not be systematic, the evaluation of biophysical data is not a main objective, however some analysis is possible.

In March 2001 seven FDTs that included *Gmelina* were established. The data for two of these sites, which were managed systematically, are presented here. The trial sites in Karamabura, Sumbawa and Manamas, Timor are characterized by steep slopes (30–45°), low precipitation (700–1000 mm/year), long dry seasons (7–9 months/year), clay loam soils with limited potential for annual crop production, and pre-existing unmanaged grasslands. Species planted included short-rotation species – *G. arborea*, *Paraserianthes falcataria* and a *Eucalyptus* hybrid (*E. urophylla* × *E. grandis*); and long-rotation species – *Swietenia macrophylla* and two sources of *Tectona grandis* (a clone and a landrace). A private company donated seedlings of the *Eucalyptus* hybrid and the *T. grandis* clone; seed of the other species is from Java. At each site 3 replications per species where established at 3×3 m spacing. Number of trees planted per species varied. Each trial is about 1 ha in size and contains about 1100 trees. Under supervision of NGO staff, in accordance with project guidelines, farmers recorded tree survival and randomly selected 10 trees per replication to measure height and basal diameter or diameter breast height (dbh). Measurements were conducted in September 2001 and December 2002. Height and diameter means were compared using Tukey's test (HSD) based on individual tree data.

Results

Pre-project survey

Thirty-five percent of the surveys were returned. Respondents identified 39 priority species, including multipurpose trees (MPTS), fruit/estate crops and timber species. *Gliricidia sepium*, *Leucaena leucocephala* and *Calliandra calothyrsus* were identified as priority species by 74%, 48% and 43% of the respondents, respectively. Priority timber species are *S. macrophylla* (30% of respondents), *T. grandis* (26%) and *P. falcataria* (26%). *Gmelina arborea* was identified by 8% of the respondents, primarily in Nusa Tenggara. Seed shortages are a universal problem; no respondents have direct access to improved quality seed. Respondents collected or purchase 75% of their seed from local sources of uncertain genetic and physiological quality. The remaining 25% is donated by development organizations, technical agencies, or universities. NGO staff, farmers and local seed dealers are unfamiliar with proper seed collection guidelines.

Seed dealer survey

Thirty-one percent of the seed dealers returned the survey. Seed of *T. grandis, S. macrophylla* and *P. falcataria* is stocked by 57% of the dealers; *G. arborea* by 45%; and *G. sepium*, *L. leucocephala* and *C. calothyrsus* by 36%. Of the dealers who supply *G. arborea* seed, 45% are located in Wonogiri, Central Java and Ponorogo, East Java (separated by only 75 km); another 35% collect *G. arborea* seed from stands of Wonogiri-Ponorogo origin. Most of the *G. arborea* dealers (85%) collect seed predominantly from industrial or farm plantations of undocumented origin. Large quantities of this undocumented seed are sold to various customers throughout the country. Only 3 (15%) of dealers collect seed from seed production areas or seed stands, located in South and East Kalimantan. This quality seed is sold primarily to forest industry and government agencies.

Farmer demonstrations trials

Growth and survival data for the trials are presented in Tables 1 and 2. The survival of most species is good, between 81 and 100%; survival of *G. arborea* averaged 99.5%. The survival of *P. falcataria* is only 61%. Of the short-rotation species, *G. arborea* showed superior height and diameter growth during the initial 6-month establishment period. After 21 months, both *P. falcataria* and the *Eucalyptus* hybrid demonstrate greater height growth. Of the long-rotation species the *T. grandis* clone demonstrates superior height and diameter growth after 21 months, followed by local *T. grandis* (land race) and *S. macrophylla*, respectively.

Table 1. Tree survival, height and DBH growth at 6 and 21 months, Sumbawa site

Species	Survival (%) 21 months	Tree height (cm)		Diameter (cm)	
		6 months	21 months	6 months	21 months
Short-rotation species					
G. arborea	100	154 ± 63a	425 ± 80a	3.0 ± 1.0a	8.5 ± 2.1a
P. falcataria	61	124 ± 48ab	489 ± 51a	1.3 ± 0.8bc	6.0 ± 0.7b
Long-rotation species					
T. grandis-clone	99	35 ± 14c	429 ± 126a	1.1 ± 0.6 c	6.1 ± 1.6b
T. grandis-seed	84	85 ± 48bc	252 ± 104b	2.3 ± 1.0ab	4.9 ± 1.3b
S. macrophylla	81	60 ± 16c	232 ± 92b	1.1 ± 0.4c	3.4 ± 1.3c

Note: different letter indicating significant mean difference ($p < 0.05$).

Table 2. Tree survival rate, height and DBH growth at 6 and 21 months, Timor site

Species	Survival (%) 21 months	Tree height (cm)		Diameter (cm)	
		6 months	21 months	6 months	21 months
Short-rotation species					
G. arborea	99	91 ± 38a	240 ± 88b	–	4.6 ± 1.2a
Eucalyptus hybrid	97	73 ± 14ab	367 ± 144a	–	4.4 ± 1.8a
Long-rotation species					
T. grandis-clone	100	50 ± 14bc	225 ± 158b	–	3.9 ± 1.6a
T. grandis-seed	89	60 ± 13bc	179 ± 143b	–	3.2 ± 1.8a
S. macrophylla	100	46 ± 9c	149 ± 57b	–	3.0 ± 1.3a

Note: different letter indicating significant means difference ($p < 0.05$).

Discussion

Gmelina arborea is a common component of government planting programs and industrial plantations in Indonesia, but not yet popular with farmers or NGOs – with the exception of those in Nusa Tenggara. It is easy to cultivate and widely grown in South and Southeast Asia. This species' potential for Indonesian farmers is exemplified by experience in the Philippines where gmelina was the basis of farmer-led, market-oriented agroforestation and land rehabilitation efforts (Garrity and Mercado 1994; Pasicolan and Tracey 1996). Philippine farmers grow gmelina in monocultures or mixed with other timber, fruit and MPTS species. Block plantations are preferred, although border and contour plantings are also established. Most farmers establish 0.25–0.75 ha of plantations at tree spacing of 3×3 m to 4×4 m (Magcale-Macandog et al. 1999; Pasicolan and Tracey 1996).

In Lampung, Central Java and Nusa Tenggara farmers cultivate mixed tree farming systems of 0.25–1.0 ha by converting marginal agricultural land or underutilized *Imperata* lands. The tree component includes timber, fruit, MPTS and estate crops (coffee, cacao, rubber, etc.). Annual crops are usually intercropped during the first 2 years after tree establishment; subsequently shade tolerant crops

may be cultivated in the understory. Farmer preferences for tree species depend on household needs and markets, but are also influenced by socioeconomic factors. Farmers with more land, higher incomes and off-farm jobs prefer to invest in long-rotation premium-value timber species and estate crops; farmers with limited income and land plant short-rotation timber species (Hariri et al. 2002; Yuliyanti and Roshetko 2002a).

Tectona grandis and *S. macrophylla* are the most popular timber species in the formal tree seed sector (Roshetko and Mulawarman 2002) and with farmer and NGOs. In Central Java, these two species compose 74% of the trees on smallholder farms (Hariri at al. 2002). The popularity of these two species is based on their stable premium value. *Paraserianthes falcataria* is also popular with smallholders because of its on-farm utility and a stable demand, if low price, for its timber. The situation with gmelina is different. It is becoming popular in Nusa Tenggara. It is common in Central Java, but not a priority with farmers. In Lampung, gmelina has been cultivated in industrial plantations and in some villages as a border planting. There are provincial level markets for gmelina wood, but market linkages with smallholder producers are not developed (Yuliyanti 2000). In some places, gmelina is associated with government land rehabilitation programs, disliked by farmers and thought to have inferior growth rates and wood quality. Only 7% of Lampung forest nurseries produce gmelina seedlings, solely for government programs; by comparison 93% of these nurseries produce seedlings of *T. grandis* or *S. macrophylla* to meet market demand (Yuliyanti and Roshetko 2002b). Our farmer partners in Lampung now express a strong interest *Acacia mangium* because it performs well in FDTs and a strong market for its wood exists. Prior to the establishment of FDTs, *A. mangium* was almost unknown composing only 1% of the trees in home gardens (Roshetko et al. 2002). This experience indicates that gmelina could also become popular with smallholders, if good performance was demonstrated in trials and smallholder access to wood markets develop.

Although FDTs results are preliminary and limited to Nusa Tenggara, there is sufficient experience with gmelina in the project area to make assessments. *Gmelina arborea* has performed well in FDTs, demonstrating excellent survival and growth. Observations show that gmelina grows well under farmers' conditions of low management and no soil amendments on good to fair sites, but performs poorly on degraded infertile sites. This agrees with smallholder experience in the Philippines (Bertomeu, in preparation). In trials, *G. arborea* and *P. falcataria* have been susceptible to strong winds, often leaning away from the prevailing winds. Across the project sites, farmers choose narrow tree spacing, 4×2 m to 3×3 m, to make the most of their limited land resources. At the FDT sites farmers start to prune side branches at 6 months to improve stem form, decrease shading of companion crops and decrease wind damage. Pruning usually reduces live crown ratio (LCR) to only 40%. In the Philippines, annual heavy pruning starting at 18 months (retaining a LCR of 20–30%) reduced *G. arborea* dbh by 3 cm (20%) at 3.5 years, compared to annual light pruning (retaining a LCR of 60–70%). Some farmers retain a live crown of only 10%, severely inhibiting growth (Bertomeu, in preparation). Smith (1962) recommends LCR of 40–50% to maximize diameter

growth and clear wood production. Heavy pruning of 2-year-old trees spaced at 3×2 m increased upland rice and mungbean production by 2.5 and 5 times, respectively (Miah 1993). As trees grow they will need more space to maintain fast growth. However, farmers are very reluctant to thin their trees. A recommended solution to this dilemma is to establish alternative rows on fast- and slow-growing timber species. The premise being that short-rotation species will be harvested in 5–8 years for household or local market needs, and long-rotation species will be harvested for more lucrative markets in 20–30 years. The rotation age reported for gmelina is 8–12 years by farmers (Yuliyanti 2000), 7–10 years by forest industry (Roshetko et al. 2002) and 5–7 years in the Philippines (Magcale-Macandog 1999). However, trees are harvested at 3–5 years if farmers need money. Outside of Lampung, experience indicates that rotation age and market price of *G. arborea* is similar to *P. falcataria.* After analyzing smallholder timber markets, Yuliyanti (2000) reports farmers maximize profit by producing and selling sawn timber of *G. arborea* opposed to selling logs; the opposite is true for premium timber species. Most smallholder-produced timber is small-diameter and satisfies household or local market needs. Some larger diameter, quality logs of premium timber species are sold in national markets.

The gmelina trees in the trials and some neighboring areas exhibit inferior stem form, similar to reports from the Philippines (Bertomeu, in preparation) and Costa Rica (Piotto et al. 2002). This likely results from the use of inferior germplasm, as most of the seed comes from the Wonogiri-Ponorogo area where seed collection guidelines are not used. With *G. arborea* seed source selection is very important in regards to survival, health and productivity (Wijoyo 2001). Thus it is wise to invest in seed of superior provenances or landraces to establish smallholder plantations. In evaluating extensive international trials, Lauridsen et al. (1995) concludes that local landraces of gmelina are appropriate for most regions, including Southeast Asia. This indicates that on-farm seed production is a viable option when stands are established from good quality seed sources and managed under technically sound guidelines.

As reported by Franzel et al. (1998), utilizing FDTs has been a low-cost method to increase farmer participation in species evaluation and agroforestry research, as well as to enhance the effectiveness of research activities to meet farmers' needs and improve their welfare. Partners credit the FDTs with: (i) demonstrating the advantages of good quality germplasm (species, provenances, clones and seed source); (ii) expanding interest in tree farming; and (iii) developing farmer innovation. As trees mature, partners plan to use the FDTs as on-farm seed sources, in conjunction with management guidelines developed by the project (Mulawarman et al. 2003).

Conclusion

Although on-farm experience is limited, gmelina is a viable option for smallholder tree farming in Indonesia. The species grows well in combination with other tree

species and agricultural crops under conditions of low management and no soil amendments on fair to good sites. *Gmelina arborea* seems to hold promise as one component of a smallholder timber production system where short-rotation and long-rotation species are planted in alternate rows; with short-rotation species intended for household, village or provincial markets and premium-quality long-rotation species intended for national markets. The management options for gmelina particularly pruning and thinning (harvesting) regimes and their effect on the productivity of agricultural intercrops, are poorly understood and need to be further developed. Rotation ages of 7–10 years seem reasonable for smallholder conditions. Farmers stand to profit most by selling sawn boards of gmelina as opposed to logs. Most of the gmelina seed available in Indonesia is of uncertain quality. It is recommended to invest in seed of superior provenances or landraces to establish smallholder plantations; and manage these stands under technically sound guidelines as local seed sources. The ultimate success of gmelina as a smallholder timber species depends on (i) demonstrating its potential under smallholders' conditions and (ii) developing access to reliable profitable wood markets. Efforts to achieve this are best designed and implemented in partnership with smallholder farmers and NGOs.

Acknowledgements

The authors wish to thank Manuel Bertomeu for sharing data from his Ph.D. dissertation, currently in preparation, and the NGOs Lembaga Pengmenbangan Masyarakat Pedesaan (LPMP) and Yayasan Mitra Tani Mandiri Timor Tengah Utara (MTM TTU) for assisting farmer partners. This work is supported by the Indonesia Forest Seed Project, Bandung, Indonesia.

References

Franzel S. et al. 1998. Farmer-designed agroforestry trials: farmers' experiences in western Kenya. In: Franzel S. and Scherr S. (eds) Trees on the Farm: Assessing the Adoption Potential of Agroforestry Practices in Africa. CABI Publishing, Wallingford, UK, pp. 111–123.

Garrity D.P. and Mercado A.R. 1994. Reforestation through agroforestry: smallholder-driven timber production on the frontier. In: Raintree J.B. and Francisco H.A. (eds) Marketing Multipurpose Tree Species in Asia. Proceedings of an International workshop held in Baguio City, Philippines, 6–9 December 1993. Winrock International, Bangkok, Thailand.

Hariri D., Mulawarman and Roshetko J.M. 2002. Socio-Economic Characteristics of Smallholder Tree Farmers in Gunung Kidul and Wonogiri Districts Indonesia. International Centre for Research in Agroforestry (ICRAF) and Winrock International, Bogor, Indonesia.

Lauridsen E.B., Kjaer E.D. and Nissen M. 1995. Second Evaluation of an International Series of *Gmelina* Provenance Trials. DANIDA Forest Seed Centre, Humlebaek, Denmark, 120 p.

Magcale-Macandog D.B., Menz K., Rocamora P.M. and Predo C.D. 1999. Smallholder timber production and marketing: the case of *Gmelina arborea* in Claveria, Northern Mindanao, Philippines. Int. Tree Crops J. 10: 61–78.

Miah M.G. 1993. Performance of selected multipurpose tree species and field crops grown in association as affected by branch pruning. Ph.D. Dissertation, Central Luzon State University, Munoz, Nueva Ecija, Philippines.

Ministry of Forestry 2001. Statistik kehutanan 2001. Http://www.dephut.go.id.

Mulawarman, Roshetko J.M., Sasongko S.M. and Irianto D. 2003. Tree Seed Management – Seed Sources, Seed Collection and Seed Handling: A Field Manual for Field Workers and Farmers. International Centre for Research in Agroforestry (ICRAF) and Winrock International, Bogor, Indonesia.

Pasicolan P. and Tracey J. 1996. Spontaneous Tree Growing Initiatives by Farmers: An Exploratory Study of Five Cases in Luzon, Philippines in Improving Smallholder Farming Systems in Imperata Areas of Southeast Asia. The Australian National University, Canberra and The South East Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Laguna, the Philippines.

Piotto D., Montagnini F., Ugalde L. and Kanninen M. 2002. Performance of forest plantation in small- and medium-sized farms in the Atlantic lowlands of Costa Rica. For. Ecol. Manage. (in-press).

Roshetko J.M. 2001. Strengthening Germplasm Security for NGOs and Smallholders in Indonesia, First Annual Report. International Centre for Research in Agroforestry (ICRAF) and Winrock International, Bogor. Indonesia, 32 p.

Roshetko J.M. and Mulawarman 2002. Direktori Penyedia Benih Pohon di Indonesia. International Centre for Research in Agroforestry (ICRAF) and Winrock International, Bogor, Indonesia.

Roshetko J.M., Delaney M., Hairiah K. and Purnomosidhi P. 2002. Carbon stocks in Indonesian home garden systems: can smallholder systems be targeted for increased carbon storage? Am. J. Alternative Agric. 17: 138–148.

Smith D.M. 1962. The Practice of Silviculture. 7th edn. John Wiley and Sons, New York.

Tomich T.P., Kuusipalo J., Metz K. and Byron N. 1997. *Imperata* economics and policy. Agrofor. Syst. 36: 233–261.

Yuliyanti 2000. Analisis pemasaran kayu di Propinsi Lampung (Timber Market Analysis in Lampung Province). Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia.

Yuliyanti and Roshetko J.M. 2002a. Karakteristik Sosio Ekonomi Rumah Tangga Petani dan Pengaruhnya terhadap Pilihan Berusahatani Tanaman Pohon-pohonan oleh Petani di Kecamatan Pakuan Ratu, Kabupaten Way Kanan dan Kecamatan Muara Sungkai, Kabupaten Lampung Utara, Propinsi Lampung. ICRAF, Bogor, Indonesia.

Yuliyanti and Roshetko J.M. 2002b. Direktori Penghasil Bibit Pohon Buah-buahan, Kayu-kayuan dan Perkebunan di Propinsi Lampung. International Centre for Research in Agroforestry (ICRAF) and Winrock International, Bogor, Indonesia.

Wijoyo F.S. 2001. The benefits of tree improvement cooperatives to serves breeding and *ex situ* conservation programs of *Gmelina arborea*, Roxb. In: Thielges B.A., Sastrapradja S.D. and Rimbawanto A. (eds) *In situ* and *Ex situ* Conservation of Commercial Tropical Trees. Faculty of Forestry, Gadjah Mada Universtiy, Yogyakarta, Indonesia, 574 p.