MINISTRY OF FORESTRY OF INDONESIA
IN COOPERATION WITH
INTERNATIONAL TROPICAL TIMBER ORGANIZATION

ITTO PD425/06 Rev. 1 (I)

Production and Utilization Technology
for Sustainable Development of Eaglewood (Gaharu)
in Indonesia

TECHNICAL REPORT NO. 1

Identification of Eaglewood (Gaharu) Tree Species Susceptibility

by :
Irnayuli R. Sitepu, Erdy Santoso, and Maman Turjaman

R & D CENTRE FOR FOREST CONSERVATION AND REHABILITATION
FORESTRY RESEARCH AND DEVELOPMENT AGENCY (FORDA)
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Authors	:	Irnayuli R. Sitepu, Erdy Santoso, and Maman Turjaman
Institution's full name, address	:	R&D Centre for Forest Conservation and Rehabilitation; Jalan Gunung Batu No. 5 Bogor, Indonesia; e-mail : turjaman@gmail.com
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PREFACE

The gaharu-development project of the so-called ITTO PD425/06 Rev.1 (I) was responsible for conducting several activities, one of which turned out the output entitled "Identified tree species". This output consisted of (1) Reviewing on existing literature on eaglewood species, potency, distribution, and cultivation; (2) Conducting field survey on eaglewood at natural and plantation area; and (3) Identifying selected susceptible eaglewood stand. These activities were conducted by the National Experts and Consultants, who were very competent and proficient in their field.

To find the gaharu literatures either in Indonesian or in English is difficult as their stocks are still very limited. Conducting the field survey related to the gaharu-yielding trees is not easy either, and nor is carrying out the identification of gaharu tree stands which are very potential to produce gaharu, suitable with the Indonesia's condition. Nevertheless, in the end the researchers should strive hard as capably as they could formulating their research results and interpretation to draw up conclusions and reach the target they want in these outputs.

This report was prepared and arranged based on field research, literature study, and discussions as performed intensively by the groups of gaharu farmers and other stakeholders. This report can expectedly bring some benefits to the policy holders of gaharu production and gaharu practitioners in the field.

Maman Turjaman
Project Coordinator ITTO PD425/06 Rev.1 (I)
R & D Centre for Forest Conservation and Rehabilitation
FORDA, the Ministry of Forestry, Indonesia

SUMMARY

The fragrant wood gaharu, known by many names including eaglewood, agarwood, aloeswood, jingkoh or oudh is considered the world's most expensive wood. Gaharu has been used in many ways for over two thousand years including incense in Buddhist, Hindu, and Islamic ceremonies, and as a significant component of traditional Ayurvedic, Tibetan, and Far Eastern Medicine and Middle Eastern perfurmes.

Gaharu plants are native to South and Southeast Asian countries : Bhutan and India, Myanmar, Lao PDR, Cambodia, Vietnam, Thailand, Malaysia, the Philippines, Indonesia, and Papua New Guinea. However, population of gaharu tree have declined and their existence is threatened according to the 2007 IUCN Red List. All species of *Aquilaria* and *Gyrinops* are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Appendix II. Other genera in the family of the Thymelaeaceae known to produce gaharu include *Gonystylus*, *Aetoxylon*, *Enkleia*, *Wikstroemia*, and *Phaleria*.

Referring to the review results from several literatures about the available gaharu trees, it can be inferred that Indonesia signifies as a country that exhibits the highest diversity in gaharu-yielding trees throughout the world, in that it owns more than 26 species, which are widely scattered from Aceh until Papua Province. The gaharu-yielding trees that grow naturally still exist in Indonesia, but unfortunately in number they tended to become limited, thereby causing difficulties in their inventory work. The natural gaharu trees that are still left can be converted to the seed-developing trees by the community staying around the forest. Meanwhile, the gaharu-yielding trees as already planted by the community around the forest, grow at more than 40 regencies, which in number reached more than two million gaharu-yielding trees planted at the farmer-owned land areas. These area data still do not cover those regarding the gaharu-tree area owned by the gaharu-exporter enterprisers who are each obligated to plant two ha area of gaharu trees.

From the survey and identification results on the gaharu-yielding trees that grow in Indonesia either those from the nature or the plantation, there were found eight tree species that develop gaharu favorably and affording the potency to be further developed, which comprise *Aquilaria malaccensis*, *A. microcarpa*, *A. beccariana*, *A. hirta*, *A. cumingiana*, *A. filaria*, *A. crassna*, and *Gyrinops versteegii*. These species can be cultivated by the stakeholders, and their gaharu products can be increase through the induction process.

Cultivation of gaharu plants is not difficult. Seed are still abundant and cuttings technology is available. Seedlings prefer shady, moist conditions, but large adult tree sometimes can withstand full sunlight. *Aquilaria* was found to have wide distribution suggesting it could be cultivated on many soil types, especially upland marginal soil in Indonesia. In several plantation locations in West Java, gaharu tree grows quite favorably in flat to undulating landscape, low to high temperature (20-32°C), and high rainfall (>1500 mm/year), hard soil texture (clay), fast drainage, pH of about 4.5-5.1, very low to high base saturation (1.2%-78.8%) and low toxic element.

The stakeholders are suggested to cultivate those eight gaharu-yielding trees, which afford the potency to develop gaharu naturally as well as through the accelerated

inoculation-technology for the gaharu-developing fungi. The securing of the residual natural gaharu tree stands deserves rationalization to all the stakeholders, in order to rigorously maintain them as the gaharu stand seeds for the local community. Construct collection of native gaharu variety in Indonesia in the guarantee area such as conservation area. Construct map of genetic variety in Indonesia which is very important for the next conservation strategy of the species target. The developing of those eight gaharu-yielding trees can be encouraged for their mass-scale development in the forms of community-managed plantation forest or industrial plantation forest.

From the data regarding the existence of gaharu trees as already planted at various Indonesia's regions, this can provide information about the awareness of government as well as the community around forest concerning the progress in securing and sustaining the genetic sources as well as raw material sources of gaharu-yielding trees at several locations in Indonesia. The cultivation of gaharu trees should not become the hindrance to the development of gaharu trees in the entire regencies of Indonesia, at the centres of gaharu production in Indonesia. Those eight gaharu-yielding trees could serve as the dependable species that deserve further development and cultivation, as those species belong to the genus of *Aquilaria* dan *Gyrinops*, and moreover have been listed in Appendix II of the CITES.

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1
INTRODUCTION

Gaharu (agarwood, eaglewood, aloeswood, jinkoh, or oudh) has long been appreciated for its multipurpose uses, range from incense for religious and traditional ceremonies, perfume, medicine and ornamental functions in many countries. The occurrence of this-so-called the wood of the gods has been strongly surrounded by myths and history. Gaharu use is mentioned in the Old Testament as 'aloe' or 'ahaloth' in Psalm 45:8. Gaharu is the only tree in the Eastern myth that has been descended to Man from Eden garden (Duke, 2008). In Egypt and Japan, gaharu was used to embalm dead bodies. In India and Cambodia, it is used for traditional and religious ceremony.

The resin compound of gaharu is highly commercial. Resin impregnated in the heartwood a number of gaharu-producing species is due to fungal infection. Two mostly known genera are *Aquilaria* and *Gyrinops* that are native to Southeast Asia with Indonesia, Malaysia, Vietnam, Cambodia, Thailand, Laos and Papua New Guinea being the main producing countries, and Singapore being the central trade country (Persoon, 2007).

Natural forests have been the main resource for gaharu collection for many years. However, gaharu hunters usually cut down the whole trees to find the resin and this practice has diminished gaharu population in the wilds and consequently has led gaharu-producing tree species under a threat of extinction. Major harvesting of gaharu was recorded between the 1980s and early 1990s in East Kalimantan caused by high demand for gaharu and was due to diminishing supply from countries like Vietnam and Cambodia (Barden *et al.,*2001 *in* Gunn *et al*., 2003). This excessive hunting activity has caused significant reduction of wild gaharu stocks within a short period of time. Similar activity also occurred in Papua after gaharu hunters landed in 1996 that has led to an ending of gaharu harvesting from its natural habitat (Persoon, 2007). 1998 was the first officially recorded year for gaharu discovery and harvesting in Yapsiei, May River and Ama villages in West Sepik, Papua New Guinea (Gunn *et al*., 2003). Harvesting of gaharu in these countries involve professional and traditional collectors. Professional collectors sponsored by Chinese and bogus trades were sometimes dropped by helicopters to hunt for gaharu (World Wide Fund for Nature, 1999).

In November 1994, *Aquilaria malaccensis* Lamk. was initially listed in CITES (the Convention on the International Trade in Endangered Species of Wild Flora and Fauna), Appendix II to prevent this species from extinction. However, continual excessive gaharu exploitations have then put two genera *Aquilaria* and *Gyrinops* in CITES, Appendix II, only ten years later. CoP13 Prop.49 (TRAFFIC, 2004) listed 24 species of the genus *Aquilaria* and 7 species of the genus of *Gyrinops*. CITES regulates the permitted quota for gaharu export in order to sustain gaharu existence, and yet, Indonesia, in particular, has not been able to meet the quota because it has become more difficult to collect gaharu from its natural habitat because they are dissapearing.

Species of *Aquilaria* have been harvested for millenia in South and Southeast Asia for their resinous gaharu from which cosmetic and pharmaceutical products are made. *Aquilaria crassna* Pierre ex Lec. is the species that occurs in central Thailand, Cambodia,

Laos, and Vietnam. Agarwood-bearing trees are mentioned in a 13th century account of Angkor Wat. In Thailand, *A. crassna* remains only in protected areas where it is heavily poached. It has been traditionally harvested sustainably by shaving wood from living trees; the wood is either chopped from near the base to search for the darkened heartwood (gaharu), or it is removed with special knives which also stimulates the development of more gaharu in the fresh wound. Although the bark does not regrow over the shaved wood, such trees usually survive and may reproduce provided that enough of the trunk remains. If more than half of the trunk has been removed, the tree is likely to fall. However, the economic crisis of 1997 in SE Asia has resulted in an increase in the number of poachers who fell trees in search of the valuable gaharu (Zhang *et al*., 2008).

Due to a significant increase in gaharu demand and high prices of gaharu, efforts have taken places to implement technology for stimulating gaharu production artificially, for a much faster process. Traditional wisdom combined with scientific knowledge have been implemented with numerous approaches to find the most efficient gaharu induction technology that will be able to fulfill the demand and at the same time conserve the remnants in the wilds.

The objective of this technical report is to give thorough information concerned with identification of eaglewood (gaharu) tree species susceptibility. This technical report based on three activities of the project, as follows : (i) reviewing on existing literture of gaharu species, potency, distribution and cultivation; (ii) conducting field survey on gaharu natural and plantation areas; and (iii) identifying selected susceptible gaharu stands.

2
APPLIED METHODOLOGY

2.1 Reviewing on existing literature of gaharu species, potency, distribution and cultivation

The data and information related with gaharu used to review are searched from libraries and internet, include: published journals, factsheet, leaflets, online information, thesis, and personal interview with expert of gaharu. In the process of review, a limited access to download online journals has been an obstacle in searching for literatures. On the other hand, published information has been largely dominated by facsheet-like publication which is not peer-reviewed by editors. This also indicates that information or publication of gaharu in well-known journals is still lacking. For conducting a review on the state-of-the-art of gaharu research and development, searching for literatures has been conducted. Literatures were obtained from libraries: FORDA, Bogor Library, BIOTROP Library; and websites. The literatures consist of technical report, proceedings, books, national-scale journals, international-scale journals Communications with gaharu experts will also be regarded as significant source for the review. This activity is of significance for formulating strategic and state-of-the-art action for ensuring accomplishment of the project.

2.2 Conducting field survey on gaharu natural and plantation areas

Surveys have been conducted in several locations, such as South Kalimantan, West Kalimantan, Bangka Island, and Lombok Island. Criteria for selecting sites for the plantation establishment include gaharu potency in the site, accessibility to the sites (road condition, type of transportation), feasibility, security to ensure the project completion, visual condition of social economy of forest community, enthusiasm of forest community if the project will be established within the area. The survey activity is still ongoing particularly for areas managed and/or belonged to stakeholders that are eager to cultivate and produce gaharu in specific locations.

2.3 Identifying selected susceptible gaharu stands

Rapid identification method of gaharu-producing trees was carried out by surveying in the fields. Gaharu-producing trees, naturally produced and artificially induced through inoculation, were observed. Observation was narrowed down on naturally-formed wounding area and ant holes on trees. Trees which were inoculated by gaharu-forming fungi, wounded physically by nailing, and treated with oil and sugar were also observed. Rapid identification of gaharu formation was carried by color observation (brown and blackish) and wood burning to detect aroma raised from it. Test was done in several locations with three repetitions and five trees for each repetition.

3
PRESENTATION OF THE DATA

3.1 Potency, distribution, and cultivation of gaharu tree species

Aquilaria and *Gyrinops* are the two most important gaharu-producing genera, within the family of Thymelaeaceae (Order: Myrtales and Class: Magnoliopsida). There are slight differences in reports on the number of species within each genus. TRAFFIC-CITES-CoP13 Prop.49 (2004) recorded 24 species belong to the genus *Aquilaria* and 7 species belong to the genus of *Gyrinops* (Table 1). On the other hand Ding Hou (1960 *in* Gunn *et al.*, 2004), reported there are 12 species belonging to the genus *Aquilaria* and 8 species belonging to the genus *Gyrinops.* These trees naturally occur in at least 12 countries: Bangladesh, Butan, Cambodia, Indonesia, Lao PRD, Malaysia, Myanmar, Philippines, Thailand, Vietnam and Papua New Guinea (Barden *et al*. in Gunn *et al.*, 2004).

Compton (2002) reported three gaharu-producing species originated from Papua Island. Two species, *A. filaria* and *Gyrinops versteegii* are found in Papua (formerly Irian Jaya) and the only species, *G. ledermannii* is from Papua New Guinea (PNG, TRAFFIC PC12 Doc.8.3, 2002). This PNG gaharu species was firstly found and harvested in approximately 1998 for its resinous wood in the Yapsiei, May River, and Ama Villages in West Sepik (Gun *et al.,* 2004). The first reported taxonomic work determined the species as *Gyrinops ledermannii*. Later report by Gunn *et al.* (2004) hovewer suggested five of the eight species Gyrinops, have been found in New Guinea island : *G. ledermannii*, *G. caudate*, *G. podocarpus*, *G. salicifolia* and *G. versteegii*. Except *G. walla* found in Sri Langka, the other seven are distributed east of the Wallace Line which is a transitional biogeographical zone that marks Asia zone to the west and Australian zone to the east.

Gaharu-producing species is characterized by small flower similar to that of jasmine and the fruit is bitter (Figure 1). The fruit does not fall when it is ripe, but it tossed the seeds to the surrounding ground (Prosea, 1999). Gaharu tree was firstly introduced by Arabic in Aceh, Sumatra. From here, the tree spread to the southern part of Sumatra, Kalimantan and Papua. In 1991, gaharu tree was found in Kayan Mentarang National Park, East Kalimantan.

Gaharu is commonly found in primary and secondary forest at 850 m above sea level (asl) with 1,500 – 6,500 mm/year with 14-28ºC (Prosea, 1999). Gunn *et al.* (2004) reported the range of gaharu occurrence is about latitude 27°N to 10°N30'S and longitude 75°E to 149°E.

The most important genus, *Aquilaria* spp. are typical of understorey species (Figure 2). *Aquilaria malaccensis, A. beccariana, A. crassna, A. filaria, A. hirta, A. microcarpa* are of six *Aquilaria* species native to Indonesia (Ding Hou, 1960 *in* Suhartono and Newton, 2001). These six species are primarily found in lowland and upland Sumatra, Kalimantan, Maluku and Irian Jaya (Suhartono and Newton, 2001).

Figure 1. Seeds of gaharu. (1-2): *Aquilaria malaccensis*; (3-4): *Gyrinops versteegii*.

Figure 2. Gaharu tree. (i) natural gaharu tree (*A. malaccensis*) ready to inoculate in Bangka Island; (ii) gaharu tree plantation (*A. microcarpa*) in West Kalimantan.

Generally, flowers grew on terminal branches among the foliage, but a few flowers of *A. crassna* occur along the trunk (cauliflory) (Suhartono and Newton, 2001). Flowers are 50 to 10 mm long. Suhartono and Newton (2001) who observed reproductive ecology of *Aquilaria* spp. in 1997-1998 reported that flowering and fruiting of *Aquilaria* spp. were around June-July in West Kalimantan, September-October in East Kalimantan, September and December in Bogor Botanical Garden, and April to December in plantation area about 2 km north of Bogor (Figure 3). Generally, the onset of flowering to produce seed takes about three months in plantation area (Annex 1, 2, 3, and 4). Further Suhartono and Newton (2001) noted that smaller trees of *A. malaccensis* and *A. microcarpa* produced more seeds than larger and older ones. Seeds of *Aquilaria* had no dormancy (recalcitrant) and will germinate soon after seed maturation.

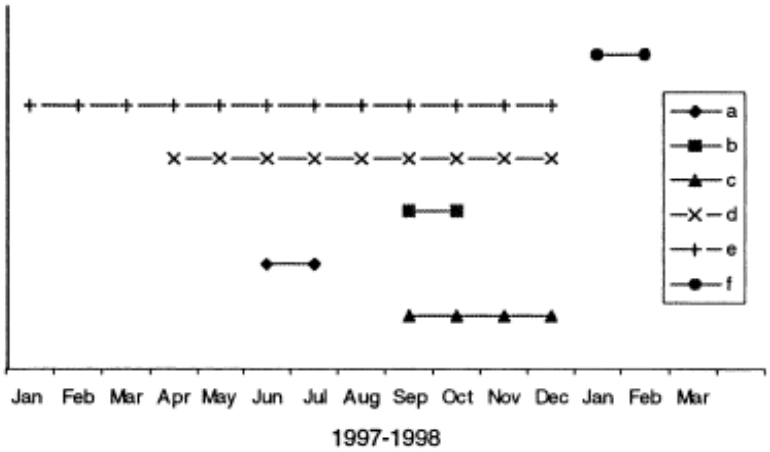

Figure 3. Flowering phenology of *Aquilaria* spp. in natural forest, plantation and Botanical Garden (a) *A. malaccensis* and *A. microcarpa* in West Kalimantan; (b) *A. microcarpa* in East Kalimantan; (c) *A. malaccensis, A. microcarpa,* and *A. beccariana* in Botanical Garden; (d) *A. crassna, A. malaccensis* and *A. microcarpa* in plantation, Bogor; (e) *A. filaria* in plantation, Bogor; (f) *A. hirta* in plantation, Bogor (Source: Suhartono and Newton, 2001).

Upon ripening, fruits of *Aquilaria* spp. split loculicidally in half from the apex, and the seeds are hanging on thin threads for about one hour before the threads break and the seeds are scattered (CIFOR, 1996 and Ding Hou, 1960 *in* Suhartono and Newton, 2001).

Below is specific description of species belonging to mostly the genera *Aquilaria* and *Gyrinops* as well as other less important gaharu-producing species.

3.1.1 *Aquilaria malaccensis* Lam.

Aquilaria malaccensis is one of the most important gaharu-producing tree, however due to severe exploitation in its natural habitat, this species has been categorized as endangered and is included in *Appendix* II CITES. The genus *Aquilaria* consists of a number of species in South East Asia – Pacific.

Flowers are green to dirty yellow (Suhartono and Newton, 2001). Flowering season in Botanical Garden occurs between September and December. Flowering season in plantation area, 2 km north of Bogor occurs April to December. In natural forest, seed

production of *A. malaccensis* > 40 cm dbh (diameter breast height) declines, while in Botanical Garden trees of 10-30 cm dbh showed to produce more seeds than those of comparable size grown in natural forest. It was estimated that this species of 20-60 cm dbh produced less seeds than *A. microcarpa*, between 3,900 and 13,270 seeds/tree. Seeds start to germinate 15 day after sowing.

Aquilaria malaccensis has been found in India, Burma, Malaysia, Phillipines and Indonesia. In Indonesia, it is found mainly in Sumatra (Sibolangit, Bangka, Jambi, Riau and South Sumatra), Kalimantan, Sulawesi, Moluccas and Papua. *Aquilaria malaccensis* has been found in primary and secondary forests, mainly in lowland and on hillsides at altitude of 200-750m asl. It grows well in sandy soils and areas having Koeppen climate type A-B with temperatures of 14-32°C and annual rainfall of 2,000-4,000 mm.

Aquilaria malaccensis reaches up to 20 – 40 m tall and 60 cm in diameter. Young bark is light brown with fine hairs, older bark is smooth and whitish in color. Without resin, wood is white, light and soft, however resinous wood is hard, dark and heavy. Leaves are characterized by alternate, elliptic or lanceolate, 3-3.5 cm wide and 6-8 cm long with 12-16 pairs of veins. Inflorescens a terminal or axillary umber. Flowers hermaphroditic, up to 5 mm long, fragrant and yellowish green or white (Figure 4).

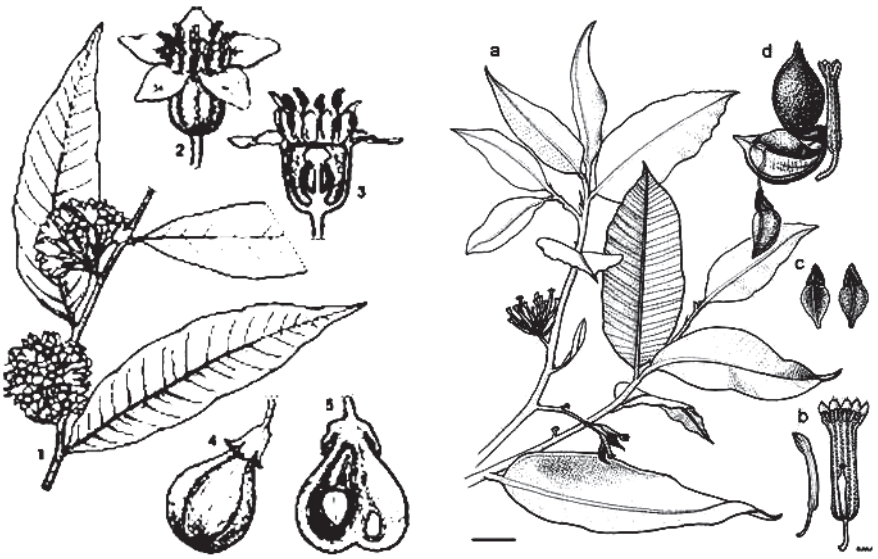

Figure 4. (1): *Aquilaria malaccensis* Lam.1. twig, 2 flower, 3. longitudinal section of flower, 4. fruit, 5. longitudinal section of fruit. (Source: Plant Resources of South East Asia 19) and (2): *Gyrinops ladermannii.* a- branchlet habit; b- flower bud (left), opened flower (right); c- seed dorsal view (left), ventral view (right); d- dehisced fruit emerging from lateral slit of floral tube with one seed hanging out on funicle; Herbarium specimen Zich 315, CANB Accession Number 531408. *Botanical illustration : Sharyn Wragg.* (Zich and Compton 2001 *in* Gunn *et al.,* 2003).

Fruit is green in color, egg-shaped capsule, leathery exocarp with fine hairs, 4 cm long and 2.5 cm wide. There are two seeds per fruit. Seed is blackish brown incolor, ovoid, and densely covered with red-brown hair. There are approximately 1,500 seeds per kg. At the age of 5-6 years, the tree starts flowering and fruiting, and medium size tree is reported to produce about 1.5 kg of seed during good seed years. Seasons for

flowering and fruiting are dry season. In Sumatra, flowering and fruiting season is twice a year. The seasons are July-August and March-April for flowering which have mature fruits in November-December and July-August, respectively. Mature fruits have blackish brown colour and they should be collected directly from the tree.

3.1.2 *Aquilaria crassna*

This species is the most widely known gaharu species from Indochina (Adelina, 2004). The Vietnamese government has enlisted *A. crassna* as endangered (Burfield, 2003). *Aquilaria crassna* is found widely in Thailand (Nobuchi and Siripatanadilok, 1991). Flowering season in plantation area, 2 km north of Bogor occurs April to December (Suhartono and Newton, 2001). In general, seeds germinate 9 – 15 days after sowing and this species had the highest germination success (92%) compared with the other 5 species (Suhartono and Newton, 2001).

3.1.3 *Aquilaria microcarpa*

Flowers are white to yellow in color (Suhartono and Newton, 2001). Flowering season in Botanical Garden occurs between September and December. Flowering season in plantation area, 2 km north of Bogor occurs April to December. In natural forest, seed production > 50 cm dbh declines, while in Botanical Garden trees of 10-<40 cm dbh showed to produce more seeds than those of comparable size grown in natural forest. It was estimated that this species of 20-60 cm dbh produced between 13,260 and 19,280 seeds/tree. In general, seeds germinate 9 – 15 days after sowing.

3.1.4 *Aquilaria beccariana*

Flowers are green to yellowish in color (Suhartono and Newton, 2001). Flowering season in Botanical Garden occurs between September and December. In general, seeds germinate 9 – 15 days after.

3.1.5 *Aquilaria filaria*

Flowers are white to yellowish green in color (Suhartono and Newton, 2001). Flowering season in plantation area, 2 km north of Bogor occurs all year around. In general, seeds germinate 9 – 15 days after sowing and this species had the lowest germination rate (53%) compared with the other 5 species.

3.1.6 *Aquilaria hirta*

Flowers are white in color (Suhartono and Newton, 2001). Flowering season in plantation area, 2 km north of Bogor occurs during rainy season in January. Seeds start to germinate 9 day after sowing.

3.1.7 *Gyrinops versteegii* (Gilg.) Domke

Gyrinops versteegii (Gilg.) is found in eastern part of Indonesia: Sumbawa, called *Seke,* in East Alor, Lombok, Flores, Sumba, and Papua (Mulyaningsih and Yamada, 2007). In Sumbawa, *G. versteegii* grows on the hillside (400-800m above sea level) ranging from Tartar village (Doro Tambiung Mountain) in West Sumbawa to Lambu village (Doro Saboke Mountain) in East Sumbawa. These plants grow in secondary and primary forests with high humidity, with *Ficus* sp., *Eugenia* spp., *Garcinia* sp., *Calophyllum* spp.,

Maranthes corymbosa Bl., *Sterculia foetida* L., *Schleichera oleosa* (Lour.) Oken., etc. (Mulyaningsih and Yamada, 2007).

In Sumba, this plant grows on brown, thin humus soil found in primary forest in Riwuta and on the foot of Meja Mountain, West Sumba. In Alor, this plant was planted in field with *Erytrina* sp., and the soil around the seedlings was mulched with rice straw and sprinkled well with water. In Sumbawa and Alor Island, this species grows as shrub, 1-4m height, 1-10 cm diameter, while in Flores Island, it grows as trees (Figure 5).

The description of the shrub was 1-4m height, 1-10 cm diameter, the plant still young, it was not in flowering yet. *Young branchlets* pubescent, bark gryish. *Leaves* chartaceous to subcoriaceous, pubescent, on the nerves and veins beneath, glabrescent or glabrous, dull and light green in beneath, shinning and dark green above, elliptic-oblong, lanceolate, 8.7-15 by 2.2-5.2 cm; base cuneate, apex up to 0.5-1 cm narrow-acuminate; nerves and veins similar, numerous, slightly oblique and parallel, 24-46 pairs; petiole, short, 3-6 mm, pubescent.

In Flores the the tree is found to have 10-17½ m height, 25-30 cm diameter. *Young branchlets* pubescent, bark gray. *Leaves* chartaceous to subcoriaceous, pubescent, on the nerves and veins beneath, glabrescent or glabrous, dull and light green in beneath, shinning and dark green above, elliptic-oblong, ovate-oblong, or obovate-oblong, 8-15 by 1½-5 cm; base cuneate, apex up to 2 cm narrow- 366 acuminate; nerves and veins similar, numerous, slightly oblique and parallel; petiole short, 3-5 mm, pubescent. *Fruits* yellow or orange, slightly obovoid or ellipsoid, 2-2¾ by 1-1½ cm, shortly acuminate to the apex, attenuate to the base. *Seed* ovoid, Plano convex, 9 by 6 mm, with a caruncle-like appendage at the base, ± 2 mm thick.

In West Sumba, shrub or tree of this species is found, 2 m up to 25 m height, diameter 3 cm up to 40 cm. *Young branchlets* pubescent, bark gray. *Leaves* chartaceous to subcoriaceous, pubescent, on the nerves and veins beneath, glabrescent or glabrous, dull and light green in beneath, shinning and dark green above, elliptic-oblong, ovate-oblong, or obovate-oblong, 8-15 by 1½-5 cm; base cuneate, apex up to 2 cm narrow-acuminate; nerves and veins similar, numerous, slightly oblique and parallel; petiole short, 3-5 mm, pubescent.

Figure 5. *Gyrinops versteegii* gaharu tree plantation mixed with choco-tree in Flores island, East Nusa Tenggara.

3.1.8 *Gyrinops decipiens* Ding Hou

This plant was found in primary forest with thin humus on the side and the top of the Ganda Dewatan mountain in Buttu Ada and Salusampe, Salubaka and Tampakura villages, Mamuju, the Tapusaang mountain in Karama village, Mamasa, and the Kapusaan mountain and the Tunggumanu mountain in Karosa in West Celebes. *Gyrinops decipiens* was also found in Kulawi, Tuwulu village, the Ulu Karosa river, Tembok Jerman and Lengke mountains around the Towuti Lake in Central Celebes; and in mountains in North Luwu in South Celebes (Mulyaningsih and Yamada, 2007).

Shrub to tree, 2 m up to 17 m height, diameter 3 cm up to 30cm. *Branchlet* fissure shallow to deep, light to dark gray, glabrous to pubescent. *Leaves* chartaceous to subcoriaceus, above glabrous, below pubescent scattered on the vena, shining on both surfaces, elliptic-oblong, lanceolate 7.5-23.5x 2.6-6.8 cm; base acute-acuminate, base caudate (0.52.0 cm long). Vena parallel, 23-39 pairs, elevation visible on below and obscure on above. Inflorescent axilar or terminal on the short branchlet in the axilar, umbel, consisting of 1-6 flowers, pedicle 2-5 mm, pubescent, brachtea opposite on the base of pedicelus, *a crescent*, rounded and thick on the apex of pedicle; pedicelus 1-3 mm. *Flower* like club, calyx tube pubescent outside, 4-6x2 mm long, calyx lobe 1,5x1 m. *Fruit* ovoid-oblong, 1-1.5x0.8-1.3 cm, color orange when fruit mature, two locus, 1-2 seeds each fruit. *Stipes* 7 mm, emerges on the base to mid of calyx lobe. *Seed* planocovex, 6x(5-7)mm, caruncle 5 mm. *Flowering* and *Fruiting* season on July-August.

Mulyaningsih and Yamada (2007) divided this plant into two varieties, i.e., *gaharu beringin* and *gaharu cabut*. *Gaharu beringin* or *Gyrinops decipiens* var. *microphylla* Mulyaningsih & Yamada var. nov. Character: tree, fissured bark deep. *Leaves* subcoriaceous relative small, lanceolate, 7.5-17.5x2.6-4.5 cm, vena 23-30 pairs, petiole 3-5 mm, pubescent. *Gaharu beringin* is produced during the decay process in specific wood. Since 2003, in some villages such as Dara, Maepi and Lere, North Luwu (South Celebes) and Tampalopo and Tampakura villages, Mamasa (West Celebes) cultivated this species. *Gaharu cabut or Gyrinops decipiens* var. *macrophylla* Mulyaningsih & Yamada var. nov. Character: Shrub, fissured bark shallow. *Leaves* chartaceous, more weigh, elliptic-oblong, 14.5-23.5x6.0-6.8 cm, vena 36-39 pairs, *gaharu* forming in whole wood tissue of plant.

3.1.9 *Gyrinops salicifolia* Ridl.

Gyrinops salicifolia grew in Dosay village, Sentani, Papua. This plant was cultivated by a person as decoration plant, because of its good canopy and leaves. Gaharu from Sentani and Jayapura was taken from this hill (Mulyaningsih and Yamada, 2007).

Slender shrub, up to 2 m. Branchlet light brown, pubescent. *Leaves* sparsely pubescent on the midrib and sometimes on the nerves and veins beneath, lanceolate to linear-lanceolate, 1½-10 by $^{1}/_{5}$-1 cm; base cuneate apex acuminate and pointed; nerves and veins similar and equally strong, slightly visible beneath, obscure above; petiole ⅓½ mm.

3.1.10 *Gyrinops ladermannii* Domke

Gyrinops ladermannii resembles *G. salicifolia*, but it grows as shrub of small trees with 7-10 m high and 13-15 cm in diameter. The leave is broader, the angle of leave and ranchlet is larger (Figure 4). Branchlet has darker color, and the wood is harder. This plant grows in secondary forest with *Callophylum* sp. on lime soil with thin humus.

It was found on a hill in Maribau village, 50-200 m above sea level, Sentani, Jayapura, Papua (Mulyaningsih and Yamada, 2007).

Leave subcoriaceous, obovate-oblong to lanceolate, 6½-12 kali (1½) 2½-5 cm; pubescent scattered on vein and midrib beneath and glabrous above. Base acute-cuneate, apex acuminate to caudate, nerves spread, visible, dense, curve, ascending face to tip. *Inflorescentia* pseudo lateral or terminal, sessile, consisted of 2-3 flowers, pedicellus thin, 3-5 mm. Calyx tube cylinders, 13 mm long, diameter 1½ mm. Calyx lobe ovate, 1½-2 kali ½ mm, outside acute, pubescent, inside obtuse, tomentose. *Petaloid* square, $^{3}/$ x ½ mm, obtuse, villous. Stamen sessile, oblong, 1-1¼ x $^{1}/$ mm. Fruit pyriform 1¾ x ⅓cm^{5} (included stipe 3 mm and apex up to 4 mm acuminate or caudate), pannose, irregular, wrinkled to transversal. *Seed* 2 or 1, one abortion, 9 mm long (included caruncle 3 mm), villous.

3.1.11 *Gyrinops caudate* (Gilg.) Domke

Gyrinops caudate was found in Agat, Mappi and Boven Digul and Merauke, West Papua. It grows in primary forest in the swamp, 5-20 m above the sea, among the sago plant, the most common soil type is sandy clay over clay. Cultivation was found in Aboge and Ecy village, District Assue, Mappi (Mulyaningsih and Yamada, 2007).

Shrub or tree up to 17 m by 36 cm. *Branchlets* grayish, whitish pubescent and glabrescent. *Leaves* chartaceous, glabrous, dull beneath and shining above, elliptic-oblong, ovate-oblong, rarely lanceolate, 6-13 by 1½-4 cm; base cuneate; apex up to 1½ cm, acuminate; nerves and veins scarcely distinguishable, numerous, parallel, visible beneath, obscure above; petiole ± 3 mm. *Inflorescences* axillary or on the terminal of short branches, 12-18 flowers, peduncle 2-8 mm. *Flowers* c. 5 mm pedicelled 5-7 mm, floral tube copular, 3-4 mm long, calyx lobes oblong, 1 mm long, petaloid appendages transverse oblong, c. ½ mm long; stamen subsessile, slightly longer than the appendages. Ovary ovoid, densely pillose; style very short; stigma capitate. *Fruit* protunding from the flower, rhombicus-oblong, contricted from the base to apex, pubescent, 2$^{1}/$ cm included 5 mm stipes, apex acuminate, two locus with 2 seeds. *Seeds* ovoid, apex acuminate c. 5 mm included caruncle 1 mm. *Flowering* and *fruiting* season on August-September.

3.1.12 *Less important gaharu species*

1. *Excoecaria agallocha* L. (Euphorbiaceae)

Exocoecaria agallocha is called *gaharu buaya* (crocodile gaharu) because its gaharu production smells like fired wood and less fragrance. The smoke can irritate eyes (Mulyaningsih and Yamada, 2007). The price is usually low and the product is used for mixing material of joystick (*hio*) or incense. This plant can be found along beach and composes mangroves in Somau Island.

2. *Wikstroemia androsaemifolia* Decne

This species is found in primary forest in Meja Mountain. Gaharu from *Wikstroemia androsaemifolia*, known as male *gaharu* or red gaharu is less preferable because of its spicy smell and the smoke irritates eyes (Mulyaningsih and Yamada, 2007).

Shrub, young branchlets slightly flattened at the nodes, densely appressed pubescent, glabrescent. *Branches* terete, reddish brown, glabrous; axillary buds densely covered

with golden-coloured hairs. *Leaves* papery, glabrous, rarely sparsely hairy on the lower surface and especially on the nerves and veins of young leaves, in dry state light-greenish, light brown or greenish-brown to brownish and shining on the upper surface, pale greenish, light-yellowish-green or light-brown and dull on the under surface, elliptic or ovate-oblong, 1¾-5½(8-) by ¾-2½(-4) cm; base acute, apex acute to narrow-acute, very rarely obtuse; nerves 8-11 pairs, elevated below and slightly depressed above, obliquely spreading towards the margin and the curved upward; veins almost as distinct as the nerves, loosely reticulate beneath, obscure above; petiole ± 2mm.

3. *Phaleria capitata* Jack

Phaleria capitata grows in Kapusaan Puncak and Tiga Puluh Puncak Mountains, Mamasa, West Celebes and in some villages around the Towuti Lake in Central Celebes. This species is also called *gaharu buaya and* less preferable because the fragrance is not good. The gaharu is used as a mixture in the making of joystick and for craft (Mulyaningsih and Yamada, 2007).

4. Phaleria microcarpa

Phaleria microcarpa was found in Papua with local name '*gaharu puk-puk'*. It produced smoky, bitter and unpleasant fragrant when burnt. It does not have commercial value. The bark was used to create *bilums* (traditional woven carrying bags) in the upper Sepik, Papua (Mulyaningsih and Yamada, 2007).

5. *Phaleria nisdai* Kanehira

This plant distributes in Papua New Guinea and was cultivated in Yomdory village Biak Papua. Shrub c. 2 m, branchlets reddish-brown. *Leaves* lanceolate, ovate-oblong, 8½-14 by 2½-4 cm, base cuneate, apex acuminate and narrow c. 1½ cm, glabercent on the both surfaces, dull beneath, nerves 5-9 pairs, elevation, decendent, veins reticulate, beneath distinct, obscure above. Inflorescences terminal and or at a long axils of branchlets, umbelliform, 10-12 flowers, one peduncle each nodes, peduncles 6-8 mm, small bracts at the base, involucral bracts 2, 2½ by ½ mm opposite, oblong, persistent or caudocous when anthesis. *Floral tube* c. 1½ cm, Floral tube gradually enlarged towards the top, glabrous outside. In side, calyx lobes oblong or ovale 4 by 2 mm glabercent on the both surfaces, papillate, appendages petaloid, stamens, styles exerted up to 6 mm, ovary. *Fruit* obovate slightly compressed and constricted from the base to apex, usually 2 fruits opposite each peduncle, yellow when ripe, 3-4½ by 5-6½ cm, two locus usually with 2 seeds. *Seeds* subglobous c. 2 by 1½ cm slightly compressed.

Table 1. Scientific names, synonyms, common names of *Aquilaria* and *Gyrinops* and distribution

No.	Scientific Name	Synonims	Common Names	Distribution Area	Ecosystem
1	*Aquilaria beccariana* van Tiegh.	*Aquilaria cumingiana* (Decne) Ridley var. *parviflora* Airy Shaw; *Aquilaria grandifolia* Domke; *Gyrinopsis grandifolia* Quis.	Gaharu; garu tanduk (Kalimantan); mengkaras putih (Sumatra); Gaharu, gumbil, njabak (Malaysia)	Extend from peninsular Malaysia to Sumatra Common in Borneo	Found Primary forest from the low land up to 825 m, rarely in swampy forest

No.	Scientific Name	Synonims	Common Names	Distribution Area	Ecosystem
2	*Aquilaria hirta* Ridl.	*Aquilaria moszkowskii* Gilg.	Chamdan, audate, ,kayu chamdan, sahare (Madura)	Malay Peninsula (Trengganu, Pahang, Johore), Singapore, East Sumatra (Senamaninik), Riau, Lingga islands.	Grow on hill slopes, from the lowland up to 300 m
3	*Aquilaria microcarpa* Baill.	*Aquilariella microcara* van Tiegh*; Aquilariella borneensis* van Tiegh*; Aquilariella borneensis* Boerl	Tengkaras (Madura); hepang (Bangka); engkaras (Dayak); karas or sigi-sigi (Bugis); kumbil, garu, tulang (Madura)	Malay Peninsula, Sumatra (Sijunjung, Palembang and Lampung), Belitung, Bangka and throughout Borneo.	Grows on lowland forest up to 200 m.
4	*Aquilaria cumingiana* (Decne) Ridl.	*Gyrinopsis cumingiana* Decne*; Decaisnella cumingiana* O.K.*; Gyrinopsis cumingiana* var. *Pubescens* Elm.*; Gyrinopsis decemcostata* Hall.f.*; Gyrinopsis pubifolia* Quis.	Alahan, magaan, palisan (Tagalog); bago (Mbo), binukat (Ak. Bis.); butlo (Neg.); dalakit (S.L.Bis.); magwalen (Sub.); pamaluian (Bag.); giba kalo (Halmahera)	South Borneo (Sampit region), Philippines (common), and Moluccas (Morotai and Halmahera)	in primary forest at low and medium altitudes.
5	*Aquilaria audate* (Oken) Merr.	*Aquilaria filaria (Oken)* Merr.*, Gyrinopsis brachyantha* Merr., *Cortex filarius* Rumph., *Pittosporum ferrugineum* var. *filarium* DC., *Pittosporum filarium* Oken, *Aquilaria tomentosa* Gilg, *Gyrinopsis bracyantha* Merr.. *Gyrinopsis acuminate* Merr. A. *_audate_e* Quis.J.	Agé (Sorong), bòkuin (Morotai), lason (Ceram), kasjik (Tehid), malowassi (Uliansers)	Philippines, Mollucas, West New Guinea	in lowland forest, up to 130 m.
6	*Aquilaria brachyantha (Merr.) Hall.f.*	*Gyrinopsis brachyantha* Merr.	-	Luzon: Cagayan Province	in primary forest at low and medium altitudes.
7	*Aquilaria urdanetensis (Elmer) Hall*	*Gyrinopsis urdanetensis* Elmer	Mangod, makolan (Mbo)	Mindanao: Mt. Ur daneta	in the mossy forest on exposed ridges, about 1700 m.
8	*Aquilaria citrinaecarpa (Elmer) Hall.f*	*Gyrinopsis citrinaecarpa* Elmer	Agododan (Mbo)	Mindanao	on moist compact soil of forested ridges, about 1300 m.
9	*Aquilaria apiculata* Elmer	-	-	Mindanao: Bukidnon province	in dry and mossy forest at 1100-1800 m.
10	*Aquilaria parvifolia* (Quis.) Ding Hou	-	-	Luzon	on forested slopes at 1000 m.
11	*Aquilaria rostrata* Ridl.	-	-	Malay Peninsula (Pahang, Gunung Tahan).	
12	*Aquilaria crassna* Pierre ex Lecomte	-	-	Cochinchina and Cambodia	
13	*Aquilaria banaense* Phamhoang Ho	-	-	Viet Nam	
14	*Aquilaria khasiana* H. Hall.	-	-	India (Khasia).	
15	*Aquilaria subintegra* Ding Hou	-	-	Thailand	
16	*Aquilaria grandiflora* Bth.	-	-	China.	
17	*Aquilaria secundana* D.C.	-	-	Moluccas	
18	*Aquilaria moszkowskii* Gilg	-	-	Sumatra	

No.	Scientific Name	Synonims	Common Names	Distribution Area	Ecosystem
19	*Aquilaria tomentosa* Gilg	-	-	New Guinea	
20	*Aqularia bailonii* Pierre ex Lecomte	-	-	Cambodia	
21	*Aquilaria sinensis* Merr.	-	-	China.	
22	*Aquilaria apiculata* Merr.	-	-	Philippines (Mindanao)	
23	*Aquilaria acuminate* (Merr.) Quis.	-	-	Philippines (?).	
24	*Aquilaria yunnanensis* S.C. Huang	-	-	China	
25	*Gyrinops versteegii* (Gilg) Domke	*Gyrinops wala (non* Gaertn.) Koord.; *Branchythalamus versteegii* Gilg; *Aquilaria versteegii* Hall.	Ketemun (Lombok); ruhu wama (Sumba); seke (Flores)	Lesser Sunda Islands (Lombok, Sumbawa, Flores, Sumba); North Celebes (Minahasa) and West New Guinea. This species closely related to Gyrinops podocarpus which also found in West New Guinea.	This species scattered from the lowland up to 900 m.
26	*Gyrinops moluccana* (Miq.) Baill	*Lachnolepis moluccana* Miq.; *Aquilaria moluccana* Hall.f.		Buru and Halmahera	in rain-forest
27	*Gyrinops decipiens* Ding Hou	-	-	Central Celebes (Wavatoli, Palarahi),	in rainforest, 100 m.
28	*Gyrinops ledermanii* Domke	-	-	New Guinea (Sepik R., Mt. Pfingst)	at slope in dense virgin forest, foot of the mountain, at 0-200 m.
29	*Gyrinops salicifolia* Ridl.	-	-	Western New Guinea (Utakwa, Nabire)	in fringing rain-forest, 300 m
30	*Gyrinops _audate* (Gilg) Domke	*Brachythalamus versteegii* Gilg; *Aquilaria versteegii* Hall.f.	Niwawur	New Guinea (Sidai, Mt. Arfak)	at primary forest 5-20 m
31	*Gyrinops podocarpus* (Gilg.) Domke	*Brachythalamus podocarpus* Gilg; *Aquilaria podicarpus* Hall.f.; *Gyrinops ladermanii (non* Donke) Merr & Perry	Kokkoree (Asmat)	West New Guinea (Ramoi, Sorong, Monep, Idenburg)	in primary forest, from lowland up to 750m.

(Source: TRAFFIC-CoP13 Prop.49, 2004)

3.1.12.1 Silviculture of Gaharu

Although gaharu has been known since ancient times, intensified research on a broader aspects of gaharu has just begun in the last ten years. One of these aspects is silviculture of gaharu. Research conducted by R & D Centre for Forest Conservation and Rehabilitation, FORDA of the Ministry of Forestry found that propagation of gaharu plants is not difficult. Gaharu can be propagated from seeds and cuttings. However, cultivation of gaharu plantation in a large scale has a high risk of pest and disease attack. This chapter provides silvicultural practice for gaharu plant.

1. Cultivation (Propagation using seeds, cuttings and tissue culture)

Seeds of gaharu are collected while they are still hanging on their mother trees because gaharu fruits crack and throw their seeds before they fall to the ground. Seedlings, on the other hand can be collected from underneath their mother trees. To date, propagation from seeds is still much cheaper than cuttings because seeds stocks are still abundant in the field and can be harvested every year from mother trees in the field. Gaharu seeds, however, is recalcitrant and its germination is affected by storage periods and conditions. A study by Subiakto *et al.* (2009) revealed that germination percentage of non-stored seeds (direct seeding) was 82% and down to 42% after being stored for 8 weeks at room temperature. Germination was further declining to 24% if the seeds were stored in refrigerator at 4°C for 8 weeks.

Study on vegetative propagation by using cuttings was done by adopting by KOFFCO (Komatsu-Forda Fog Cooling) System (Figure 6). Using this system, Subiakto *et al.* (2009) found that the best growth media and watering interval for gaharu shoots cuttings were mixtures of coconut dust and paddy husk of 1 : 1 ratio, and twice a week of watering, respectively. These treatments showed the highest rooting percentage, i.e. 69%.

Tissue culture of *A. crassna* and *A. malaccensis* was studied by Tientum in 1995. Shoots of *A. crassna* grown on Woody Plant Medium with and without auxin, produced roots. But addition of 0.5 mg/l IBA stimulated the highest rooting percentage. The author found that survival rate of *A. crassna* plantlets was 90% after transplantation to the field.

Figure 6. Silviculture of gaharu. (1-2): Propagation by cuttings with KOFFCO system; (3): Effect of inoculation with beneficial microbes for promoting growth; (4): Gaharu plantation.

In vitro propagation of *Aquilaria agalocha* by He *et al.* (2005) on MS medium supplemented with 1.3 micromol/L BA (6-benzylaminopurine) generated many shoot buds in the first 7 weeks, and 1.3 micromol/L BA+0.5 micromol/L NAA (naphthaleneacetic acid) elongated the buds in another 7 weeks, 2.3 shoots 2 cm in length per explant were obtained within 14 weeks. Plantlets were rooted on 1/2 MS medium after being immersed in 5 micromol/L NAA for 48 h, 96.7% of the roots grew up two weeks later. All plantlets that survived acclimatization grew well in the pots.

2. Inoculation of beneficial microbial to promoted plant growth

In 2002, Tamuli and Boruah observed the association of arbuscular mycrorrhizal fungi (AMF) with gaharu tree in Jorhat district of the Brahmaputra Valley. They isolated different AMF but found that *Glomus* is the dominant genus. Among the *Glomus* spp., *Glomus fasciculatum* is the most dominant followed by *Glomus aggregatum*. Further studies revealed that AMF and plant growth promoting bacteria (PGPR) promoted early growth of gaharu seedlings. Inoculation of AMF, *Glomus clarum* and *Gigaspora decipiens,* increased growth of 180 days old *A. filaria*, under greenhouse conditions (Figure 6). Growth acceleration was indicated by percentage of AM colonization up to 93%, plant growth (height, diameter and biomass dry weight), survival rate, and nitrogen (70-153%) and phosphorus (135-360%) concentrations (Turjaman *et al.,* 2006). Two PGPR, *Burkholderia* sp. CK28 (IAA-producing bacteria), and *Chromobacterium* sp. CK8 (mycorrhization helper bacteria) accelerated height growth of *Aquilaria* sp. in in the nursery. Percentage of height increase over non-inoculated control seedlings ranges from 12.2 to 38.7%, five months after inoculation. Effect of inoculation was no longer observed after seedlings were transplanted to the fields, probably due to interaction with soil microflora (Sitepu *et al.,* 2009).

3. Pest and Disease

Gaharu plants cultivated in a large scale is prone to pest and disease attack. Some important pests and diseases have been found attacking several locations of gaharu plantations in Indonesia with various level of attack (Table 2; Figure 7).

Table 2. Pests and Diseases of gaharu plants in several locations in Indonesia

No.	Pests	Host	Location	Damage intensity
Pest				
1.	*Heortia vitessoides*	*A. microcarpa, A. malaccensis, A. crassna, Gyrinops* sp.	Bogor, West Java	+
2.	*Heortia vitessoides*	*A. malaccensis*	Sukabumi, West Java	+
3.	*Heortia vitessoides*	*A. microcarpa*	Carita, Banten	+ + +
4.	*Heortia vitessoides*	*A. microcarpa,*	Central Bangka	+ +
5.	*Heortia vitessoides*	*A. malaccensis,*	Bodok, West Kalimantan	+ +
6.	*Heortia vitessoides*	*A. beccariana*	West Kalimantan	+ +
7.	*Heortia vitessoides*	*A. malaccensis, A. microcarpa*	Kandangan and Barabai, South Kalimantan	+
8.	Stem borer	*Gyrinops* sp.	North Sulawesi	+
9.	*Heortia vitessoides*	*Gyrinops* sp.	Bali	+

No.	Pests	Host	Location	Damage intensity
10.	*Heortia vitessoides*	*Gyrinops* sp.	Lombok, West Nusa Tenggara	+
11.	Stem borer	*Gyrinops* sp.	Lombok, West Nusa Tenggara	+
Disease				
12.	Mildew	*A. microcarpa*	Carita, Banten	+
13.	Mildew	*A. microcarpa*	Pulau Laut, South Kalimantan	+
14.	Heart rot	*Gyrinops* sp.	West Nusa Tenggara	+

Notes: Damage intensity: +: weak, ++: medium, +++: severe (Source: Santoso ***et al.,*** unpublished data)

The most important pest found to date is identified as *Heortia vitessoides* Moore (Odontiinae, Crambidae) (Irianto *et al*., 2010). The pest (previously *Tyspana vitessoides*), has caused severe damage to many gaharu plantations in Indonesia in the past three years, i.e. in Forest Area with Specific Purposes (Kawasan Hutan dengan Tujuan Khusus, KHDTK) Carita, Banten Province; Bodok, Sanggau, West Kalimantan Province; Kandangan, Barabai, South Kalimantan Province; Malino, East Kalimantan Province; Bali Province; and Lombok, West Nusa Tenggara Province; and South Sumatra (Erdy Santoso, *Pers. Comm.*). In 2008, the percentage of pest attack in gaharu plantation in KHDTK, Carita, reached 100%, many of the trees defoliated, and about 20 trees died because of recurring attack on newly emerging leaves. This pest has also been reported to have distributed in Fiji, Hongkong, Thailand, and North Queensland (Austtralia) (Herbison-Evams and Crossley, WWW page).

Figure 7. Pests and disease of gaharu trees. (1): Leaf eater *Heortia vitessoides;* (2): Stem Borer; (3): Colony of ants, the predator of *H. vitessoides*: (4): Hearth-rot fungi.

The caterpillars of this species are pale green with a broad knobbly black line along each side. Their head is brown. The caterpillars live in a group in a shelter made by joining a number of leaves together with silk. The caterpillars drop on silk threads if disturbed. When mature, the caterpillars descend and pupate in the soil. The adults have a striking pattern on the forewings of black on pale yellow. The hindwings are white with a broad black margin. The moths have a yellow and black banded abdomen. The wingspan is about 3 cms. The eggs are yellowish-green, and are flattened. They are laid in an overlapping cluster, like tiles on a roof (Herbison-Evams and Crossley, WWW page).

A study by Irianto *et al.* (2010) investigated pest management strategy to control the population of *H. vitessoides.* This study found that application of a mixture of systemic and contact insecticides with addition of leaf fertilizer and plant sticker effectively controlled high population of the pest. A biological control approach was also studied by using ants, predator of the pest, that build a nest on gaharu trees and keep the plant protected from the pest. This experiment is still underway but seems encouraging.

Cultivators of gaharu plants need to be aware and familiarized themselves with pest and disease of gaharu plants, and take appropriate control action to prevent from severe loss. Socialization of pest and disease management has been done by PD 425/06 Rev.1 (I) project in collaboration with R & D Centre for Forest Conservation and Rehabilitation, FORDA of the Ministry of Forestry, to local forestry offices at the provincial level, gaharu plant growers and general stakeholders.

3.2 Conducting field survey on gaharu natural and plantation area

Data was not easily collected from wild gaharu trees survey in several locations. Locations that were visited by the research team are Aceh, North Sumatera, Jambi, Riau, Bengkulu, West Sumatera, South Sumatera, Lampung, Bangka-Belitung, West Kalimantan, Middle Kalimantan, South Kalimantan, East Kalimantan, North Sulawesi, Gorontalo, West Nusa Tenggara, East Nusa Tenggara, and Maluku. Generally wild gaharu trees were spread sporadically and data collection was difficult to achieve. Distances between trees were various. There were 12 wild gaharu trees in a colony for 200 m^2 radius in one location. There were more than 250 wild gaharu trees in a 50 Ha area in Bengkulu. Wild gaharu trees in Aceh province were located in distanced forest hills which access from one tree to others were difficult. In Jambi and Bangka, wild gaharu trees were found grown around rubber plantation. Neither Local Forestry Authorities nor forest farmers could confirm the number of wild gaharu trees in their area.

In planted gaharu trees survey, gaharu research team initiated Tally Sheet to several districts. Not all the local forestry authorities/farmer associations filled the sent Tally Sheet. Table 3. showed cultivated gaharu trees potentions in Indonesia.

Table 3. Data of gaharu plantation area from some districts in Indonesia (Siran, 2011)

No	Name of District	Species	Age of plantantion (year of plantation)	Number of tree	Source of data
1	Bogor	*A. malaccensis, A. microcarpha, A. crassna*	3-15 years 2008/1989	3750	Erdy Santoso
2	Sukabumi	*A. crassna*	11 years / 2000	80	Erdy Santoso
3	Pandeglang	*A.microcarpha, A.malaccensis*	2 years / 2009	43.000	Erdy Santoso
4	Sragen	*A.filaria*	2- 6 years	22.000	Forestry office
5	Purworejo	*Gyrinops*	7 years/2003	165	Farmer
6	Sleman	*A.microcarpha*	7 years / 2004	4.000	Forestry office
7	Malang	*Gyrinops*	4 years / 2007	30.000	Farmer/private
8	Banyuwangi	*Gyrinops*	4 years / 2007	7.000	Farmer/private
9	Tapak Tuan Ds	*A. microcarpha*	10 years/2001	17.000	Farmer/private
10	Bahorok Ds	*A.microcarpha*	2-7 years/2003	125.000	Farmer
11	Sijunjung	*A.microcarpha*	7 years / 2004	750	Farmer
12	Padang Pariaman	*A.microcarpha*	2001-2003	1.500	Forestry office
13	Kota Padang	*A.microcarpha A.malaccensis*	2004	2.250	Farmer
14	Muara BungoDs	*A.microcarpha*	1-5 tahun / 2006-2010	50.000	Farmer
15	Sorolangun Ds	*A.microcarpha*	1-5 tahun / 2006-2010	75.000	Farmer
16	Lingga	*A. malaccensis*	2001-2004	11.000	Farmer
17	Riau	*A.Malaccensis*	10 tahun/ 2001	5.000	Farmer
18	Bangka Selatan	*A.malaccensis, A. microcarpa*	2008/2009	283.414	Forestry Office
19	Bangka Tengah	*A.malaccensis, A. microcarpa*	2008/2009	286.890	Forestry Office
20	Bangka Barat	*A.malaccensis, A. microcarpa*	2008/2009	29.500	Forestry Office
21	Belitung	*A.malaccensis, A. microcarpa*	2008	26.000	Forestry Office
22	Belitung Timur	*A.malaccensis, A. microcarpa*	2008/2009	9.850	Forestry Office
23	Lampung Barat	*A.malaccensis, A. microcarpa*	2004	50.000	Forestry Office
24	Lampung Timur	*A.malaccensis, A. microcarpa*	2005	30.000	Forestry Office
25	Lampung Selatan	*A.malaccensis, A. microcarpa*	2008/2009	5.000	Forestry Office
26	Sawaran	*A.malaccensis, A. microcarpa*	2009	15.000	Forestry Office
27	Tanggamus	*A.malaccensis, A. microcarpa*	2009	15.000	Forestry Office
28	Lampung Tengah	*A.malaccensis, A. microcarpa*	2007/2008	25.000	Forestry Office
29	Lampung Utara	*A.malaccensis, A. microcarpa*	2006	30.000	Forestry Office
30	Pringsewu	*A.malaccensis, A. microcarpa*	2009	5.000	Forestry Office
31	Kutai Barat	*A.malaccensis, A. microcarpa*	2007	100.000	Forestry Office
32	Pasir	*A.malaccensis, A. microcarpa*	2007	15.000	Forestry Office
33	Kutai Kartanegara	*A.malaccensis, A. microcarpa*	2006	75.000	Forestry Office
34	Samarinda	*A.malaccensis, A. microcarpa*	2006	60.000	FRI Samarinda
35	Malinau	*A.malaccensis, A. microcarpa*	2007	400.000	Forestry Office
36	Berau	*A.malaccensis, A. microcarpa*	2007	100.000	Forestry Office
37	Sanggau	*A.malaccensis, A. microcarpa, A.beccariana*	2005	143.000	Farmer group
38	Pontianak	*A.malaccensis, A. beccariana*	2006	29.800	Farmer

No	Name of District	Species	Age of plantantion (year of plantation)	Number of tree	Source of data
39	Kandangan	*A.malaccensis, A. microcarpa*	2009	20.000	Farmer
40	Barabai	*A.malaccensis, A. microcarpa*	2009	10.000	Farmer
41	Balangan	*A.malaccensis, A. microcarpa*	2005	25.000	Farmer
42	Pulau Laut	*A.malaccensis, A. microcarpa*	2003	10.000	Farmer
43	Tomohon	*Gyrinops*	2005	2.000	Farmer
44	Gorontalo	*Gyrinops*	2006	5.000	Farmer
	Total			**2.218.949**	

3.3 Identifying selected susceptible gaharu stands

Identification of selected stands which form gaharu through natural infection or inoculated was done. Observasions revealed that there were at least eight specieses wild and cultivated gaharu trees. All the eight specieses belong to *Aquilaria* or *Gyrinops*. Seven of them were Indonesian indigenous. The other one, *Aquilaria crassna*, were from Indochina (Vietnam, Kamboja, Laos, and Thailand). The Identification was based on gaharu forming process found in the wild by observing form, color, and raised aroma. After inoculation, formed gaharu was confirmed/identified by the forest farmers (Table 4; Figure 8).

Table 4. Data of identifying selected susceptible gaharu stands

Tree species	Native/Cultivated	Location	Response of gaha-ru-forming
A. malaccensis	Native	Bangka	+++
A. microcarpa	Native	Sorolangun	+++
A. beccariana	Native	Sanggau	+++
A. filaria	cultivated	Bogor	+++
A. cumingiana	Native	Maluku	+++
A. hirta	cultivated	Bogor	+++
A. crassna	Cultivated	Sukabumi	+++
Gyrinops versteegii	cultivated	Flores	+++

Figure 8. Identifying selected susceceptible gaharu stand; (i) gaharu wood decay; (ii) gaharu-forming by *Fusarium solani* origin Jambi; (iii) gaharu-forming by *F. Solani* from Gorontalo**.**

4

ANALYSIS AND INTERPRETATION OF THE DATA AND RESULTS

From the review results from various available literatures, it could be inferred that Indonesia signifies as one of the important gaharu-producing countries in the world, which owns more than 26 species widely scattered in Indonesia. The diversity of gaharu-yielding trees is quite high, and their population is distributed in Sumatera, Kalimantan, Sulawesi, Nusa Tenggara, Maluku, Papua, where they grow naturally. Abundant number of gaharu tree species are related to the varying qualities of the yielded gaharu, and consequently the gaharu consumers owe their different tests to such qualities. Variation in genetics and growth locations of gaharu trees present one of the determining factors of different gaharu-qualities. Another consideration is that the gaharu-developing fungi also take the role in affecting the qualities of developed-gaharu. Despite that, natural-gaharu products tended to decrease continuously all through the years either qualitatively or quantitatively due to the unsustainable gaharu-harvest.

In their natural habitat, gaharu is harvested by felling trees and cutting away uninfected tissue to obtain the resinous wood. Gaharu is hunted intensively by collectors due to high value of gaharu and significantly increased demand, while the supplies from the wilds have become scarce. Other concurrent activities: land clearing, forest exploitation, forest fire also contribute to the disappearance of gaharu-producing trees in a relatively short time (TRAFFIC, CoP13 Prop.49, 2004). In the past, only infected trees were cut down and harvested for gaharu, however when the trees have become rare, collectors would cut down also healthy plants regardless the low quality of gaharu (TRAFFIC, CoP13 Prop.49, 2004). When collectors are hunting for gaharu, they will harvest the whole tree without considering the species of the tree (TRAFFIC, CoP13 Prop.49, 2004). The unsustainable way of harvesting of gaharu by collectors and the diminishing trees in their natural habitat have placed two genera of gaharu, *Aquilaria* and *Gyrinops* in CITES, Appendix II as threatened genera according to the IUCN Red List in order to sustain gaharu producing species in their natural habitat. Collectors of gaharu reported that it has become more difficult to find gaharu compared to previous years (TRAFFIC, CoP13 Prop.49, 2004).

Rapid depletion of *A. malaccensis* was recorded in Gunung Palung National Park, West Kalimantan, Indonesia and the surrounding area (Paoli *et al.,* 2001). Gaharu was first harvested exclusively from near villages where trees were abundant. However, exploitation continued and extended to the protected national park area. In less than 5 years, the scientists reported that most *A. malaccensis* was removed from the park. This national park covers a total area of 100,000 ha of a diverse mosaic tropical rain forest type. At the time of survey, the density of *A. malaccensis* in was low but the species was widely distributed in six forest types: freshwater, swamp, alluvial bench, lowland sandstone, lowland granite, and lower montane. With only 20 cm in diameter at breast height (dbh) which was below the estimated 35 cm dbh, placed the species at high risk of extinction because the tree has not reached maturity. In this forest also,

regeneration of *Aquilaria* was highly variable among forest types and appeared highest in lowland standstone and lowland granite forest.

Taxonomically, *Aquilaria* and *Gyrinops* are distinguished from each other by one morphological character only: the number of stamens (Eurlings and Gravendel, 2005). The sequences obtained from the *Aquilaria* and *Gyrinops* samples analyzed indicate that wood identification based on DNA polymorphisms is possible. DNA up to 300 bp can be amplified and analyzed even if extracted from dead wood. Identification of several dry wood samples to species level and geographical regions was successful. DNA sequences were obtained from 31 Thymelaeaceae accessions encompassing 20 different species in six genera. *Aquilaria* and *Gyrinops* appear to be paraphyletic. Success in sequencing wood samples demonstrates that molecular markers provide new perspectives for agarwood identification.

In order to sustain gaharu production as well as the existence of gaharu-producing trees, Suhartono and Newton (2001) suggested increasing cultivation of gaharu in plantations. The capacity of seeds to disperse is limited, therefore a high density of trees may be established as seed orchards. Since the production rates of seeds and germination rates are high, it is potential for producing planting stock for commercial scale.

Botanics Garden Conservation International listed recommendation of essential efforts to secure and conserve the remaining wild populations of gaharu-producing species that included, as follows (Gratzfeld and Tan, 2008):

1. Strengthen institutional cooperation and coordination. Various stakeholders including local collectors, processors, traders, government and conservation agencies, botanic gardens and businesses need to take part in this action.
2. Improve capacity building and intensify training related with gaharu conservation and sustainable production that may include integrated *ex-* and *in situ* species recovery programs, silviculture and management practices
3. Establish practical conservation and sustainable production in demonstration projects, aiming to enhance 1): conservation of remaining wild populations of gaharu producing tree species (e.g. in community managed protected areas); 2): *ex situ* propagation of critically endangered species in village nurseries, local botanic gardens, etc.; and 3): subsequent reintroduction into the wild.

Many local community livelihoods depend on the wilds for harvesting gaharu and serious implementation of conservation and sustainable production practices will help to provide a complementary approach to harvesting wild trees and to relieve pressure on the remaining highly threatened gaharu-producing species.

The survey as conducted was to determine the number of gaharu trees which are quite difficult to obtain. Natural gaharu trees usually exhibit their widespread distribution. Particularly for the condition in Sumatera and Kalimantan, natural gaharu trees were found growing at the area of community-owned rubber plantation. This could happened possibly the distribution or scattering of gaharu tree-seeds was astonishingly assisted by particular chewing-animals such as squirrels, forest mice, or got carried away by the flowing run-off water. Meanwhile, in North Sulawesi and Gorontalo, gaharu trees were also found growing at the nature-preservation area or national park, but the accessibility to the gaharu-tree sites in such locations was difficult. Special for Papua area, the data

potencies of natural gaharu trees as well as those of gaharu-tree plantation were not yet available.

Data of gaharu trees which were cultivated by farmers, privates, or local forestry authorities were easier to collect. The stakeholders had started to record the number of the cultivated gaharu trees although the number might be larger that the one that we collected. Some further attempts to obtain data base of gaharu tree, as follows :

1. Continuing of further data collection to the regions, which have once become the main supplier of gaharu from the nature. Such collection can be done by a direct visit or submitting the questionnaires to the information source
2. Conducting the dissemination to the community regarding the engineering technology of gaharu products that comprises prospects and chances of gaharu products from engineering results. The knowledge about the prospect of inoculation technology will encourage the spirits of planting to farmers.
3. Changes in government policies (PP No. 8, in 1999) related to the planting (cultivating) of gaharu-yielding trees
4. Incorporating of the gaharu-yielding trees into the government program, among others: establishment of community-managed plantation forest, rehabilitation of critical land, community empowerment, etc.
5. Counseling to the community regarding the procedures of gaharu endeavors that results from cultivation.

5
CONCLUSIONS

Referring to the review results from several literatures about the available gaharu trees, it can be inferred that Indonesia signifies as a country that exhibits the highest diversity in gaharu-yielding trees throughout the world, in that it owns more than 26 species, which are widely scattered from Aceh until Papua Province. The gaharu-yielding trees that grow naturally still exist in Indonesia, but unfortunately in number they tended to become limited, thereby causing difficulties in their inventory work. The natural gaharu trees that are still left can be converted to the seed-developing trees by the community staying around the forest. Meanwhile, the gaharu-yielding trees as already planted by the community around the forest, grow at more than 40 regencies, which in number reached more than two million gaharu-yielding trees planted at the farmer-owned land areas. These area data still do not cover those regarding the gaharu-tree area owned by the gaharu-exporter enterprisers who are each obligated to plant 2-ha area of gaharu trees.

From the survey and identification results on the gaharu-yielding trees that grow in Indonesia either those from the nature or the plantation, there were found 8 tree species that develop gaharu favorably and affording the potency to be further developed, which comprise *Aquilaria malaccensis*, *A. microcarpa*, *A. beccariana*, *A. hirta*, *A. cumingiana*, *A. filaria*, *A. crassna*, and *Gyrinops versteegtii*. These species can be cultivated by the stakeholders, and their gaharu products can be increase through the induction process.

6
RECOMMENDATION

The stakeholders are suggested to cultivate those eight gaharu-yielding trees, which afford the potency to develop gaharu naturally as well as through the accelerated inoculation-technology for the gaharu-developing fungi. The securing of the residual natural gaharu tree stands deserves rationalization to all the stakeholders, in order to rigorously maintain them as the gaharu stand seeds for the local community. Construct collection of native gaharu variety in Indonesia in the guarantee area such as conservation area. Construct map of genetic variety in Indonesia which is very important for the next conservation strategy of the species target. The developing of those eight gaharu-yielding trees can be encouraged for their mass-scale development in the forms of community-managed plantation forest or industrial plantation forest.

7
IMPLICATION FOR PRACTICE

From the data regarding the existence of gaharu trees as already planted at various Indonesia's regions, this can provide information about the awareness of government as well as the community around forest concerning the progress in securing and sustaining the genetic sources as well as raw material sources of gaharu-yielding trees at several locations in Indonesia. The cultivation of gaharu trees should not become the hindrance to the development of gaharu trees in the entire regencies of Indonesia, at the centers of gaharu production in Indonesia. Those eight gaharu-yielding trees could serve as the dependable species that deserve further development and cultivation, as those species belong to the genus of *Aquilaria* dan *Gyrinops*, and moreover have been listed in Appendix II of the CITES.

ANNEX

Annex 1. Flowering and fruiting seasons of *Aquilaria malaccensis* in West Kalimantan

Annex 2. Flowering and fruting season of *A. microcarpa* in East Kalimantan

Annex 3. Fruiting season of *Aquilaria beccariana* in West Kalimatan

Annex 4. Flowering and fruiting season of *Gyrinops versteegii* in North Sulawesi

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