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THE FIRST TRULY INDEPENDENT WATCHDOG FOR THOSE WORKING WITH NATURAL AROMATIC MATERIALS

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An Agarwood Bibliography.

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Contents:

***Cropwatch comments*:** For a review of Agarwood microbiology, chemistry etc., see under http://www.cropwatch.org/agarwood.htm. For a comprehensice review of the individual threatened spp. involved in Agarwood production (*Aquilaria*, *Aetoxylon, Gyrinops*, *Gonystylus Phaleria, Wikstroemia, Enkleia* etc.) and their respective status, see Threatened Aromatic Species section of the Cropwatch Files at http://www.cropwatch.org/cwfiles.htm .

Agarwood Formation - Botanical & Taxonomic Aspects, including Identification.

Airy Shaw H. K. (1952) "Three new species of *Gonystylus* from Borneo." *Kew Bulletin* **7**(1), 73-74.

Airy Shaw H. K. (1954). "Thymelaeaceae – Gonostyloideae." In: Van Steenis C.G.G.J. (ed.) *Flora Malesiana* **1**(4), 1–349. Wolters-Noordhoff Publishing, Groningen, The Netherlands

Airy Shaw H.K. (1964) "New or noteworthy species of *Gonystylus* (Thymelaeaceae), principally from Borneo" *Kew Bulletin* **17**(3), 447-458.

Asif M.J. & Cannon C.H. (2005) "DNA extraction from processed wood: A case study for the identification of an endangered timber species (*Gonystylus bancanus*)," *Plant Molecular Biology Reporter* **23**(2), 185-192. Abstract. We applied human forensic techniques to the extraction of whole genomic DNA from processed wood samples to explore the possibility of identifying an endangered tropical timber species by using DNA sequencing technology. High-yield and high-quality DNA samples were obtained from 2 commercial wood and 3 herbarium samples. Large PCR fragments ranging from 500–800 bp were successfully amplified from 2 chloroplast and 1 mitochondrial regions in all 5 samples, indicating limited degradation of the cytoplasmic genomes. DNA extraction from stem wood taken from herbarium specimens appeared superior to that from stem wood with bark intact or from leaf samples. DNA sequences from thetrn regions allowed for easy identification of the focal species based on GenBank Blast search. Little sequence variation was observed in the 3 regions, with the mitochondrialcox3 region completely conserved. Extraction of high-quality and large intact DNA fragments makes dry wood materials amenable to

various DNA marker-based applications, including fingerprinting and historical approaches. By sampling stemwood, the wealth of historical information housed in international herbaria can be explored with minimal damage to taxonomically important features.

Barman H.K. & Nath R.K. "Pathogenicity of entomopathegenic fungi *Beauveria bassiana* on *Heortia vitessoides*, a major in sect pest of *Aquilaria agallocha* in Assam." *Insect Environment* **8**(2), 79-80.

Baas P. & van Heuven B. (2002). "*Gonystylus* spp." *CITES Identification Manual.*

Chengbung Y & Yuanhui L (1980) "Anatomical and histochemical studies on oleoresin formation in the wood of *Aquilaria sinensis* (Lour.) Gilg.." Paper at 4th Asian Symposium on Medicinal Plants and Spices, Bangcock (Thailand) 15-19 Sep 1980 *4th Asian Symposium on Medicinal Plants and Spices Abstracts*, Mahidol Univ, Bancock, Thailand. Fac. Of Science, Dept of Chem Bangcock, Thailand 1980 p108.

Compton, J. G. S. & Zich F.A. (2002) "*Gyrinops ledermannii* (Thymelaceae) being an agarwood-producing species prompts call for further examination of taxonomic implications in the generic delimitation between *Aquilaria* and *Gyrinops*." *Flora Malesiana Bulletin* **13**(1), 61-65.

Corner E.J.H. (1940) *Wayside Trees of Malaya* Vol 2 Govt. Printer, Singapore.

Debenath B..& Sinha S. (1993) "Chromosome studies in *Aquilaria agallocha* Roxb.: A New Report" *Cell & Chromosome Research* **16**(1), 38.

Debnath B., Sil S., Sinha R.K. & Sinha S. (1995) "Chromosome number and karotype of *Aquilaria agallocha* Roxb. (Thymelaeaceae)" *Cytologia* **60**(4), 407-409

Ding Hou (1960) Wolters-Noordhoff Publishing, Groningen, The Netherlands."Thymelaeaceae". In Van Steenis C. G. G. J. (eds.) *Flora Malesiana* **1**(6), 1–48.

Ding Hou (1964). "Notes on some Asiatic species of *Aquilaria* (Thymelaeaceae)." *Blumea* **12**(2):285–288.

Eurlings M.C., Heuveling van Beek H, & Gravendeel B. (2010) "Polymorphic microsatellites for forensic identification of agarwood (*Aquilaria crassna*)." *Forensic Sci Int.* 2010 Jan 5. Abstract. Tropical agarwood (*Aquilaria*) is in danger of extinction in the wild due to illegal logging. Its resin (Gaharu) is used for the production of highly valued incense throughout Asia. We have isolated and characterized microsatellite loci of *Aquilaria crassna* to detect the geographic origin of agarwood for forensic applications using a modified enrichment procedure based on the capture of repetitive sequences from restricted genomic DNA. We assessed the polymorphisms of five microsatellites amplified from fresh leaves of 22 trees from seven plantations in Vietnam and Thailand and dried leaves of a herbarium specimen of one wild tree. Cross specificity of these markers was confirmed on two related *Aquilaria* species occurring in China and Vietnam and one microsatellite locus was successfully amplified from wood and incense samples. Four of the loci were polymorphic and the number of alleles ranged from 3 to 15. The loci characterized here can provide a starting point for forensic identification of traded material and certification of sustainably produced agarwood.

Eurlings M.C.M & Gravendeel B. (2005) "TrnL-trnF sequence data imply paraphyly of *Aquilaria* & *Gyrinops* (Thymelaeaceae) and provide new perspectives for agarwood identification". *Plant Systematics & Evolution* **254**(1-2), 1-12. Abstract. The genera *Aquilaria* & *Gyrinops* (Thymelaceae, Malvales) are well known for the produc.ion of agarwood which is a highly wanted forest product of substantial economic value. The taxonomic status of *Aquilaria* & *Gyrinops* as separate genera is doubted as they are only distinguished by the number of stamens. We

investigated their status by conducting phylogenic analyses of DNA sequences from the plasmid trnL-trnF spacer. Control of international trade of agarwood is directly hampered by the failure of traditional methods such as microscopy to identify samples to species level. We therefore evaluated the potential of molecular identification of agarwood by searching for species- and region-specific plastid DNA polymorphisms. DNA sequences were obtained from 31 Thymelaeaceae accessions encompassing 20 different species in six genera. *Aquilaria* & *Gyrinops* appear to be paraphyletic. Success in sequencing wood samples demonstrates that molecular markers provide new perspectives for agarwood.

Gibson I.A.S. (1977) "The role of fungi in the origin of oleoresin deposits (Agaru) in the wood of *Aquillaria agallocha* (Roxb.)" *Bano Biggyn Patrika* **6**(1), 16-26. Abstract: A brief review is given of investigations into the cause of agaru, a valuable aromatic oleoresinous deposit found in the stems of *Aquilaria agallocha* in Bangladesh, East India and other parts of South East Asia. In previous investigations various fungi have been identified in association with agaru deposits but their causal role has not been fully established. The present investigation includes microscopic examinations and identification of fungal isolates from four samples of agaru collected in the Sylhet region of Bangladesh. From this evidence it is concluded that it is unlikely that there is a specific fungal cause for agaru. Suggestions are made for further research.

Hambali G.G & Yatazawa M. (1993) "Observations on *Aquilaria baillonii* Pierre ex Lecomte." : *Taxonomy of tropical trees for genetic diversity studies* Issue 51, pp83-4 Biotrop Special Publicns.

Hawksworth D.L.& Gibson I.A.S (1976) "*Phialophora parasitica*" CMI Descriptions of Pathogenic Fungi & Bacteria 1976, No 504.

Hawksworth D.L., Gibson I.A.S. & Gams (1976) *Transactions of the British Mycological Society* **66**, 427-431.

Hawksworth D.L. & Gibson I.A.S. (1977) "*Phialophora parasitica*" *Desr Pathog Fungi Bact* **51**, 501-510.

Hou, Ding (1964) "Notes on some Asiatic species of *Aquilaria* Thymelaeaceae.". *Blumea* **12**(2), 285-288.

Hou, Ding (1960) "*Aquilaria*" pp6-16 in *Flora Malesiana* Series 1: **6**(1-3) Thymelaeaceae ed. van Steenis C.G.C.J. (ed).

Ito M. & Gisho H. (2005) "Taxonomical identification of Agarwood-producing species." *Nat Med* **59**(3), 104-112. Abstract. Recent overexploitation in Asian tropical forests has caused serious shortages of natural resources of timber species some of which are now threatened with extinction. Agarwood-producing species belonging to *Aquilaria*, *Gyrinops*, and *Gonystylus* are listed in Appendix II of CITES as endangered. Meanwhile, attempts to produce agarwood using cultivated trees have proven unsuccessful. A scientific explanation of how resin is generated and accumulated is required to artificially produce agarwood. However, fundamental to the research is the identification of the source plant, which can be difficult. Therefore, we compared DNA sequences of some *Aquilaria* plants collected from different locations to examine whether this method was applicable and if so, which DNA region was suitable. We found the psbC-trnS region to be applicable but required authentic sequences derived from correctly identified specimens, which would be a major task. A morphological comparison of samples with herbarium specimens was performed along with the DNA sequencing, and morphological characteristics were discussed. (author abst.)

Kiet, le-C., Kessler PJA & Eurlings M. (2005) "A new species of *Aquilaria* from Vietnam." *Blumea* **50**(1), 135-141. Abstract. A new species of *Aquilaria* is described from Vietnam and keys to the flowering & fruiting specimens of all species from this region are provided. DNA sequences of nrITS1-5.8S-IT2 region seem to confirm its status as a distinct species.

Kundu, M. & Kachari, J. (2000) "Desiccation sensitivity and recalcitrant behaviour of seeds of *Aquilaria agallocha* Roxb." *Seed Science & Technology* **28**(3), 755-778 pub. International Seed Testing Association 2000.

Mabberley D.J. (1998) *The Plant Book* (2nd edn) Cambridge Univ Press.

Mandang Y. I., Wiyono B. (2002) Anatomy of eagle wood (*Aquilaria malaccensis* Lam.) and everal related species. The Fifth Pacific regional wood anatomy conference. Abstracts of papers and posters. *IAWA Journal*, **23**(4), 471.

J. & Gogol P. (2001) "Fungi Associated with the diseased wood (agarwood/agaru) of *Aquilaria agallocha* Roxb. (Fam. Thymelaeaceae) grown in Assam. *Proceedings of Seminar on Scope & Dimension of Agar Plantation in NE region*. Edits M. Ahmed, P. Gogol & G.U. Ahmed pp 61-69, AATMA, Hojai, India.

Mulyaningsih T. & Sumarjan (2002) "Formation of Interxylary Phloem & Aromatic Resin in *Gyrinops vesteegii* (Thymelaeceae)" *The Fifth Pacific Regional Wood Anatomy Conference.Abstracts from the Meeting of the IAWA Pacific Regional Group & IUFO S 5.01 (Wood Quality), Jakarta Indonesia 9-14 Sept. 2002*. IAWA Journal 2002 **23**(4), 472-3.

Nabin S., Nath S. C., Saikia N. & Dutta S. (2000) "Foliar Micromorphological Characters of Few Taxa of the genus *Aquilaria* Lamk. growing in North-east India" *Advances In Plant Sciences* **13**(2), 551-558.

Nath S. C,. Kalita J. & Saikia N. (1999) "Germination studies on the seeds of *Aquilaria malaccensis* Lamk. - A potential crop for fragrance industry." *Indian Perfumer* **43**(3), 159-163 Essential Oil Assocn of India.

Ng L.T., Chang Y.S. & Azizol L.K. (1997) "A review on agar (gaharu) producing *Aquilaria* species" *J. Tropical Forest Products* **2**(2), 272-285.

Norwati M. (2001) "Karas - an Endangered Species: a Genetic Study" *FRIM In Focus* 2001 December issue, 4-5.

Pimol Tiengtum (1995) "In vitro culture of agarwood trees (Aquilaria spp.); Kan pholiang kritsana nai saphap plot chua." *Summary: Kasetsart Univ., Bangkok (Thailand). Graduate School.* Abstract In vitro culture of various parts of *Aquilaria* spp. were studied at tissue culture laboratory, Department of Horticulture, Kasetsart University. Shoot tips and lateral buds from 2 species of agarwood trees (*Aquilaria crassna* and *A. malaccensis*) were cultured on Woody Plant Medium (WPM) and modified MS medium with half-strength of nitrate supplemented with BA, 2iP and kinetin at the concentrations rate 0, 0.25, 0.5, 1, 2 and 4 mg/l. Both media supplemented with cytokinin promoted growth and shoot proliferation. BA was the most effective for stimulating shoot multiplication, followed by kinetin. 2iP had no effect on shoot multiplication. Relatively low levels of BA (0.25, 0.5 mg/l) were effective in stimulating the multiplication and elongation of shoot tips and lateral buds. BA at high levels (1-4 mg/l) produced more number of shoots that did not elongate. Callus obtained by culturing young leaf discs on MS medium containing 0.5, 1, 1.5 and 2 mg/l 2,4-D and 2, 3 mg/l BA. But callus did not regenerate. Shoots of A. crassna produced roots on WPM medium with or without auxin. Both NAA and IBA were tested in the rooting experiments, IBA more effective in stimulate rooting. The highest rooting percentage was 65 percent in medium containing 0.5 mg/l IBA. Shoots of *A. malaccensis* failed to root. The survival rate of A. crassna plantlets was 90 percent when transplanted in nursery.

Pojanagaroon S, Kaewrak "Mechanical Methods to Stimulate Aloeswod Formation in *Aquliaria crassna* (Kritsana) trees." *Acta Horticulturae (ISHS)* **676,** 161-166 Abstract. Various mechanical injury methods were tested to induce formation of aloes wood in 4-year-old *Aquilaria crassna*

Pierre ex H. Lec. (kritsana) trees grown at Phurua Highland Agricultural Experiment Station, Phurua, Loei (950 m asl, 17°17'N 101°24'E) during February 2001 to October 2002. A sequential change in the wood coloration was observed aroundinjury sites. One month after wounding a pale discoloration occurred, followed by a darker yellow-brown discoloration after 3 months, becoming dark brown within 8-10 months and changing to black within 20 months with accompanied on burning scent. Wood block samples collected from live tree at 10, 15 and 20 months after wounding were compared among the different mechanical treatments. The results indicated that holes made with screws, wounds inflicted with chisels and bark removal with hatchets on the trunk gave dark yellow-brown to dark discoloration near injury (5-10 mm from the cut end), while nails hammered into the trunk gave dark brown to black occurring by the interaction between ferric oxide and fibers, where as hammers beated on the trunk gave only little discoloration. The larger the objects used to wound the trunk of kritsana trees, the wider the width of the discoloration ring. The rate of the formation of the discoloration ring around the wound in the rainy season (16-20 months after wounding) was 3 times higher than in the dry season (11-15 months after wounding), influenced by seasonal factors. Most treatments gave no specific aromatic kritsana scent by burning the wood samples, except only 4 treatments gave pale scent which were the holes made with screws (1.27 cm and 1.11 cm in diameter) and wounds inflicted with narrow (1 cm) and wide (2.54 cm) chisels. Moreover, the wood samples gave very low percentage yields of essential oil using a hydro-distillation method. In conclusion, mechanical injury can be used for the formation of aloes wood in kritsana trees, and the most suitable method was the holes made with screws (1.27 cm in diameter) which gave the widest discoloration ring and pale specific aromatic kritsana scent by burning.

Qui Shu-Yuan (1995) "*Aquilaria* species: *in vitro* culture and the production of eaglewood (agarwood)" in *Bajaj YPS Biotechnol Research Reports of the American Institute of Unani Medicine, Oxford NY, Christi Order, 1994*.

Qui Shu-Yuan (1999) "III. *Aquilaria* species: in vitro culture and the production of eaglewood (agarwood)" in *Medicinal & Aromatic Plants.* edited by Yashpal Singh Bajaj pub. Springer 1999.

Rao, R. K. &. Dayal R. (1992). “The secondary xylem of *Aquilaria agallocha* (Thymelaeaceae) and the formation of “agar.” *IAWA Bulletin* **13**, 163–172.

Rypacek V., Navratilova Z. (1971) “Growth of fungi in wood” *Drevarasky Vyskum* **16** (1/2), 115-22

Sadgopal & Varma B.S. (1952) “Agar oil from the wood of *Aquilaria agallocha* Roxburgh” *SPC* **25**, 169-174.

Sadgopal (1960) “Explanatory studies in the development of essential oils and their constituents in aromatic plants. Part 1: Oil of Agarwood.” *SPC* **33**, 41-46.

Schun Y. & Cordell G.A. (1985) “Studies in the Thymelaeaceae. III. Constituents of *Gyrinops walla*.” *J Nat Prod*. 1985 **48**(4), 684-5.

Shen YJ, Zhao SJ. (2007) "[Study on karyotype and giemsa C-banding of *Aquilaria sinensis*]." *Zhong Yao Cai*. **30**(7), 762-5. Abstract OBJECTIVE: To study *Aquilaria sinensis* (Lour.) Spreng chromosome karyotype and C-banding. METHOD: Sections for karvotvpe and BSG method for C-banding. RESULTS: The somatic chromosome number was 2n=16, karyotype formula was K(2n) = 2x = 16 = 6m + 6sm + 4st, based on Levan's publication in 1964. According to the method of Kuo, the chromosome based on the relative length was 2n = 16 = 4L + 4M2 + 6M1 + 2S, which belonged to "2B". 8 pairs chromosomes had 34 C-bands and the C-banding patter was 2n = 2x = 16 = 4C + 2I + 2T + 2CI+ + 2CI+ T + 2CI+ T+ + 2I+ T+. CONCLUSION: The data of karyotype and C-banding indicated A. sinensis chromosome had a relatively high asymmetry and was in the advanced stage of evolution, which offered the evidence for further genetic analysis.

Smulders M.J.M. Van 'T Westende W.P.C., Diway B., Esselink G.D., Van der Meer P.J., Koopman W.J.M. (2008) "Development of microsatellite markers in *Gonystylus bancanus* (Ramin) useful for tracing and tracking of wood of this protected species." Molecular Ecology Resources 8 (1) , 168–171. Abstract. Ten polymorphic microsatellite markers have been developed for *Gonystylus bancanus* (Ramin), a protected tree species of peat swamp forests in Malaysia and Indonesia. Eight markers were also shown to be polymorphic in other Gonystylus species. The markers will enable assessing the amount of genetic variation within and among populations and the degree of population differentiation, such that donor populations can be selected for reforestation projects. They may be used for tracing and tracking of wood in the production chain, so that legal trade in this Convention on International Trade in Endangered Species of Wild Fauna and Flora-protected timber species, derived from specifically described origins, can be distinguished from illegally logged timber.

Subansenee W., Naiyana Tongjiem, Viboon Sakekul (1985) "Fungi on agarwood [*Aquilaria* spp.]." *Report on minor forest products research, Royal Forestry Dept., Bangkok (Thailand). Forest Product Research Div..- Bangkok (Thailand), 1985*. p. 8-15. Abstract. "Isolation and identification of fungi was made from 9 agarwood samples collected from tropical rain forest in Rayong, Chanthaburi, Trad, Nakhon Ratchasima, Krabi, Trang and Pattarung. Seventeen species of fungi found on agarwood samples were *Botryodiplodia theobromae*, *Curvularia lunata*, *Fusarium oxysporum*, *Pestalotia* sp., *Cercosporella* sp., *Chaetomium spirale*, *Cladosporium* sp., *Phialogeniculata* sp., *Pithomyces* sp., *Rhizopus* sp., *Spiculostibella* sp., *Trichoderma* sp., and five unknown species. The first four species were parasitic. The other species were saprophyte."

Tamuli P., Bhuyan D., Borah P, & Nath SC (1999) "Seed-bourne fungi of Agarwood plant" I*ndian Phytopathology* **52**(3), 312.

Tamuli P., Boruah P., Nath S.C., Bhuyan D. & Samanta R (2000) "Mycofloral study on rhizosphere of *Aquilaria agallocha* Roxb." *Assam Science Society* Vol 1.

Tamuli P., Boruah P. & Nath S.C. & Samanta R. (2000) "Mycofloral study on the phyllosphere and soil of agarwood tree plantation." U.G.C. Sponsored seminar on Conservation of Biodiversity, Assam, pp 5 (2000).

Tamuli P., Boruah P., Nath S.C., & Samanta R (2000) "Fungi from diseased agarwood tree (*Aquilaria agallocha* Roxb.): two new records" in *Advances in Forestry Research 2000*, XXII ed. Ram Parkash p182-189. Abstract: "Agar is known as the results of natural infection, found as irregular patches in trunks of the standing tree of *Aquilaria agallocha* Roxb., which are of great economic importance. Two fungi, viz., *Fusarium oxysporum* Schlect. and *Chaetonium globosum* Kunze. were isolated for the first time from the diseased wood of *A. agallocha.* These two fungicolonised wood blocks of *A. agallocha* when these were inoculated artificially.

Tamuli P. & Boruah P. (2002) "Changes in free amino acids in agarwood plant under pathological condition." *Geobios - Jodhpur* **29**(4), 241-243.

Tamuli P. & Boruah P. (2002) "Vesicular-abuscular mycorrhizal (VAM) association of agarwood tree in Jorhat District of the Brahmatputra Valley." *Indian Forester* **128**(9), 991-994 Forest Research Institute. Abstract. Occurrence of VAM fungi in forest tree species is well known and are found in most ecosystems. A survey for collection of root and rhizosphere soil samples of Agarwood plant from various plantations of Jorhat district of the Brahmaputra Valley, revealed variation in per cent root colonization and number of VAM propagules in the rhizosphere soil samples. Different VAM fungi have been isolated, of which the genus *Glomus* is dominant. Among the *Glomus* spp., *Glomus fasciculatum* is the most dominant followed by *Glomus aggregatum*.

Turjaman M, Tamai Y, Santoso E, Osaki M, Tawaraya K. (2006) "Arbuscular mycorrhizal fungi increased early growth of two nontimber forest product species *Dyera polyphylla* and *Aquilaria*

filaria under greenhouse conditions." *Mycorrhiza*. **16**(7), 459-64. Abstract. Nontimber forest products (NTFPs) represent an important source of income to millions of people in tropical forest regions, but some NTFP species have decreased in number and become endangered due to overexploitation. There is increasing concern that the planting stocks of *Dyera polyphylla* and *Aquilaria filaria* are not sufficient to sustain the yield of NTFPs and promote forest conservation. The objective of this study was to determine the effect of two arbuscular mycorrhizal (AM) fungi, *Glomus clarum* and *Gigaspora decipiens*, on the early growth of two NTFP species, D. polyphylla and *A. filaria*, under greenhouse conditions. The seedlings of both species were inoculated with *G. clarum* or *G. decipiens*, or uninoculated (control) under greenhouse conditions. Percentage of AM colonization, plant growth, survival rate, and nitrogen (N) and phosphorus (P) concentrations were measured after 180 days of growth. The percentage of AM colonization of D. polyphylla and *A. filaria* ranged from 87 to 93% and from 22 to 39%, respectively. Colonization by *G. clarum* and *G. decipiens* increased plant height, diameter, and shoot and root dry weights. Shoot N and P concentrations of the seedlings were increased by AM colonization by as much as 70-153% and 135-360%, respectively. Survival rates were higher in the AM-colonized seedlings at 180 days after transplantation than in the control seedlings. The results suggest that AM fungi can accelerate the establishment of the planting stocks of *D. polyphylla* and *A. filaria*, thereby promoting their conservation ecologically and sustaining the production of these NTFPs economically.

Uchibayashi M. (2002) ["Eaglewood and eagle"] *Yakushigaku Zasshi* **37**(1),104-106. Abstract: The etymology of eaglewood (chen xiang) and its related terms with particular reference to its relation to eagle (*Aquilaria*) is discussed. It is pointed out that this fragrant wood has nothing to do with eagle. A Portuguese aguila transcribed from akil (Malay, the name of wood), perhaps underwent phonetic traction to aguia (Portuguese, eagle) in the process of being translated into French. Thus pau d'aguila (Portuguese) was transformed to bois d'aigle (French, aigle=eagle), which led to eagle-wood (English) and Adlerholz (German).

Verma V.P.S. (1977) "Trials of herbicides for inducing formation of agarwood in *Aquilaria agollocha* Roxb." *Indian Perfumer* XXI(3),151-3. Abstract: The results of trials with auxin herbicides viz., 2,4-D, 2,4,5-T and MCPA on the formation and development of agarwood in 15 year old *Aquilaria agallocha* Roxb. trees growing in Sissagar Forest Division of Assam are given. The effect of mechanical injury was also observed. The indicative trials reported in the paper have shown the said herbicides and the mechanical injury do not appear to have induced the formation of agarwood in *Aquilaria agallocha* Roxb. till one year after the treatment.

Venkataramanan M.N., Borthakur & Singh H.D. (1985) "Occurrence of Endotrophic myccorhizzal fungus in agarwood plant *Aquilaria agallocha* Roxb. *Current Sci* **54**, 928

Whitmore T.C. (ed) (1973) *Tree Flora of Malaysia* Longman Group, London.

Wollenberg E.K. "Incentives for collecting gaharu (fungal-infected wood of *Aquilaria* spp.; Thymelaceae) in East Kalimantan." *Economic Botany* **55**(3), 444-456.

Yance I., Mandang & Bambang Wityono (2001) "Anatomy of Eaglewood (*Aquilaria malaccensis*) and several related species" *Poster at 5th Pacific Regional Wood Anatomy Conference* (Yogyakarta). p471

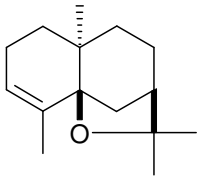
Yu Chenghung & Liang Yanhui (1980) "Anatomical & histochemical studies on oleoresin formation in the wood of Aquilaria sinensis (Lour.) Golg. In: 4th Asian Symposium on Miedicinal Plants & Spices – ASOMPS IV Sept 15-19, Bangcock, Thailand p108.

Agarwood Chemistry

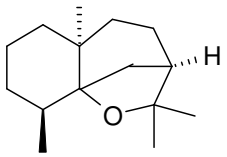
Ahmad S. (1983) "Isolation of 5-hydroxy-7,4'-dimethoxyflavone from *Gonystylus bancanus*." *Planta Med.* **48**(5), 62-3.

Alkhathlan H.Z., Al-Hazimi H.M., Al-Dhalaan F.S. & Mousa A.A. (2005) "Three 2-(2-phenylethyl) chromones and two terpenes from agarwood" *Natural Product Research* **19**(4), 367 - 372. Abstract: A new chromone, 7,8-dimethoxy-2-[2-(3'-acetoxyphenyl)ethyl]chromone was isolated from an acetone extract of the Cambodian agarwood along with two known chromones, 6-methoxy-2-(2-phenylethyl)chromone and 6,7-dimethoxy-2-(2-phenylethyl)chromone. In addition, an abietane ester and the sesquiterpene dehydrofukinone were isolated from the agarwood oil of the same origin. Structural elucidation of all isolated compounds was made based on IR, 1H and 13CNMR spectroscopic data.

Asselin A., Mongrain M. & Deslongchamps P. (1968) "Syntheses of α-agarofuran and isodihydroagarofuran." *Can. J. Chem.* **46**(17): 2817–2820. Abstract. A new synthesis of α-agarofuran (1) has been realized in four steps from ketol 3 and a stereospecific synthesis of isodihydroagarofuran (dihydro-α-agarofuran) has been achieved in four steps.



alpha-agarofuran



alpha-dihydroagarofuran

Barrett H.C. & Buechi G. (1967) “Stereochemistry and synthesis of a-agarofuran” - *Journal of the American Chemical Society*, 1967, 5665-5666. Abstract. A stereoselective total synthesis of a-agarofuran demonstrated that this and five other related furanoid sesquiterpenes have the relative and absolute stereochemistry indicated in structure **19.** Photooxygenation of the cyclohexadiene **10** yielded in addition to the anticipated endo-peroxide **11** a cross-conjugated ketone **13** presumably derived from the unstable doubly allylic hydroperoxide.

Bhandari P., Pant P., & Rastogi R.P. (1982) "Aquillochin, a coumarinolignan from *Aquilaria agallocha*" *Phytochemistry* **21**(8), 2147-2149. Abstract: Aquillochin, isolated from the whole plant of *Aquilaria agallocha*, has been shown to be a coumarinolignan, and a structure has been proposed on the basis of chemical and physical studies.

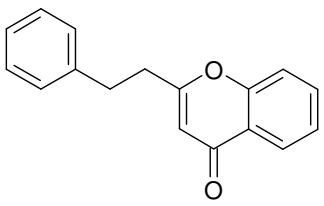
Bhuiyan N.I., Begum J. & Bhuiyan N.H. (2004). "Analysis of essential oil of eaglewood tree (*Aquilaria agallocha* Roxb.) by gas chromatography mass spectrometry." *Bangladesh J Pharmacol* **4**, 24-28. Abstract. The study was carried out to find out the differences in composition of oils obtained from healthy, naturally infected and artificially screws wounds eaglewood (*Aquilaria agallocha* Roxb.) using gas chromatography mass spectrometry analysis. Natural healthy plants agar contained octacosane (19.83%), naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]- (12.67%), 5-isobutyramido-2-methyl pyrimidine(13.52%), caryophyllene oxide (11.25%) and (.+-.)-cadinene (5.46%). Natural infected plants agar (super agar) contained cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl- (46.17%), caryophyllene oxide (33.00%) and 7-isopropenyl-4a-methyl-1-methylenedecahydronaphthalene (20.83%). Artificially screw injected plants agar contained diisooctyl phthalate (71.97%), 1H-cycloprop[e]azulen-4-ol, decahydro-1,1,4,7-tetramethyl-, [1ar-(1a.alpha.,4.beta.,4a.beta., 7.alpha., 7a.beta., 7b.alpha.)]- (9.16%), hexadecanoic acid (7.05%), naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]- (6.45%) and aristolene (5.36%). This study showed a marked difference in the oil compositions among the treatments with regards to their quality.

Connolly J.D., McCrindle R., Murray R.D.H. & Renfrew A.J. (1966) "Constituents of *Aquilaria agallocha* - Erythroxydiols" *J Chem Soc* ??

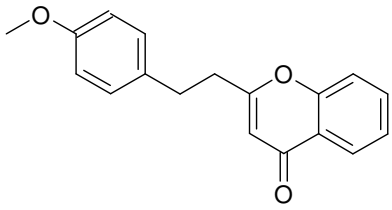
Gunasekera S.P., Kinghorn A.D., Cordell G.A. & Farnsworth N.R. (1981) "Plant anticancer agents. XIX Constituents of *Aquilaria malaccensis*." *J. Nat Prod.* **44**(5), 569-72. Abstract. The

stem bark of the Thai tree *Aquilaria malaccensis* (Thymelaeaceae) has afforded 1,3-dibehenyl-2-ferulyl glyceride, which is novel, and 12-O-n-deca- 2, 4, 6-trienoylphorbol-13-acetate. The structures of these cytotoxic compounds were elucidated by their spectral and chemical parameters.

Hashimoto K., Nakahara S., Inoue T., Sumida Y. & Takahashi M. (1985) "A new chromone from agarwood and pyrolysis products of chromone derivatives." *Chem Pharm Bull* **33**(11), 5088-91. Abstract. A new chromone, 2-(2-4'-methoxyphenylethyl) chromone (I) was isolated together with 2-(2-phenylethyl) chromone (II : flidersiachromone) from agarwood (Japanese name ; JINKOH). On pyrolysis at 150℃, I and II were found to produce 4-methoxybenzaldehyde and benzaldehyde, respectively. It is considered that these chromones, which are odorless at room temperature, contribute to the pleasant, lasting odor obtained when agarwood is burnt as an incense.

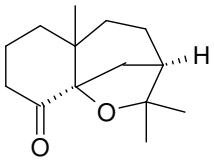


2-(2-phenylethyl)chromone



2-(2-(4'-methoxyphenyl)ethyl)chromone

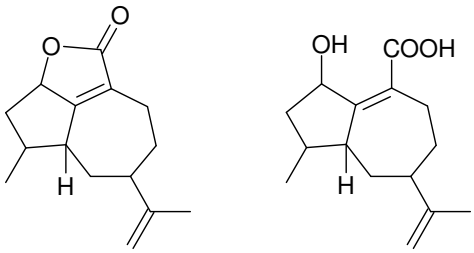
Heathcock C.H. & Kelly T.B. (1968) "Total synthesis of nor-ketoagarofuran" *Chem. Commun,* 268.



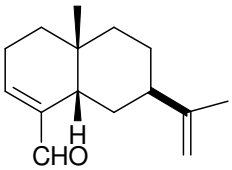
Ishihara, M., Tsuneya T., Uneyama, K. (1991a) "Guaiane sequiterpenes from Agarwood" *Phytochemistry* **30**(10), 3343-3347. Abstract Seven new sesquiterpenes, all of which have a guaiane skeleton, i.e. (–)-guaia-1(10),11-dien-15-ol, (–)-guaia-1(10),11-diene-15-carboxylic acid, methyl guaia-1(10),11-diene-15-carboxylate, (+)-guaia-1(10),11-dien-9-one, (–)-1,10-epoxyguai-11-ene, (–)-guaia-1(10),11-dien-15,2-olide and (–)-rotundone, have been isolated from *Aquilaria agallocha* (agarwood). Their structures have been established on the bases of detailed spectroscopic analyses and synthesis.

Ishihara, M., Tsuneya T., Suga M., Uneyama, K. (1991) "Three sesquiterpenes from agarwood" *Phytochemistry* **30**(2), 563-566.

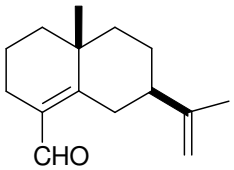
Ishihara M., Masatsugu Y. & Uneyama K. (1992) "Preparation of (–)-guaia-1(10),11-dien-15,2-olide and (–)-2-hydroxyguaia-1(10),11-dien-15-oic acid, fragrant sesquiterpenes in agarwood (*Aquilaria agallocha* Roxb.)" *Tetrahedron* **48**(47), 10265-10276. Abstract. The fragrant sesquiterpene (–)-guaia-1(10),11-dien-15,2-olide (8), isolated from agarwood (*Aquilaria agallocha* Roxb.), was synthesized starting from (–)-1,10-epoxybulnesene, which is readily available from -bulnesene in patchouli oil. The absolute configuration of the natural 8 was established by direct comparison of its optical rotation with that of the synthesized 8. It was found that (–)-2-hydroxyguaia-1(10),11-dien-15-oic acid (9), a synthetic intermediate of 8, also occurs in agarwood. Graphical Abstract. The title fragrant sesquiterpenes, isolated from agarwood (Aquilaria agallocha Roxb.), were synthesized starting from (–)-1,10-epoxybulnesene. Their absolute configurations were also determined as shown in the right figure.



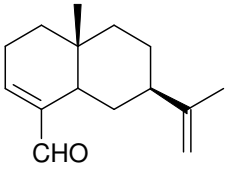
Ishihara, M., Tsuneya T., Uneyama, K. (1993) "Fragrant sesquiterpenes from Agarwood" *Phytochemistry* **33**, 1147-1155. Abstract. Two new sesquiterpene aldehydes, (-)-selina-3,11-dien-14-al and (+)-selina-4,11-dien-14-al, methyl ester derivatives of three new sesquiterpene carboxylic acids, (-)-methyl selina-3,11-dien-14-oate, (+)-methyl selina-4,11- dien-14-oate, and (+)-methyl 9-hydroxyselina-4,11-dien-14-oate, and a new nor-sesquiterpene ketone, (+)-1,5-epoxynor-ketoguaiene, have been isolated from *Aquilaria agallocha* (agarwood). Their structures have been established on the bases of detailed spectroscopic analyses and synthesis. The occurrences of dehydrojinkoh-eremol and neopetasane in agarwood were also confirmed by comparison of their mass spectral data and R(t) on capillary GC with those of synthesized samples. The odoriferous properties of some natural and synthesized sesquiterpenes are also described.



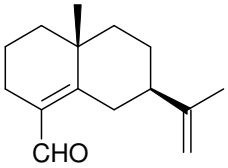
selina-3,11-dien-14-al



selina-4,11-dien-14-al



3,11-Eudesmadien-15-al



4,11-Eudesmadien-15-al

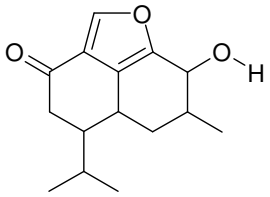
Ishihara, M. Tsuneya, T. Uneyama, K. (1993) "Components of the volatile concentrate of Agarwood." *JOER* **5**(3), 283-289. Abstract. The solvent extracts obtained from four kinds of agarwood (Kanankoh and Jinkoh), all of which were collected in Vietnam and imported via Hong Kong, were analyzed using fused silica capillary gas chromatography and mass spectrometric techniques. The difference between Kanankoh (*Aquilaria agallocha* Roxb.) and other agarwood (Jinkoh-tentatively identified as *A. sinensis* (Lour.) Gilg.) was studied by comparing the compositions of their extracts. Kanankoh contained large amount of chromone derivatives as previously reported. Moreover, it was found that two types of Kanankoh existed. One of them was rich in oxygenated guaiane and eudesmane derivatives, while the other contained oxo-agarospirol as a major sesquiterpene component. The biosynthesis of the sesquiterpenes in Kanankoh is also discussed

Ishihara, M., Tsuneya T., Uneyama, K. (1993) "Components of the Agarwood smoke on heating" *JOER* **5(**4), 419. Abstract. The smoke of two kinds of Vietnamese agarwood (Kanankoh and Jinkoh) generated by heating was analyzed by using fused silica capillary GC/MS. Kanankoh smoke contained many kinds of fragrant sesquiterpenes along with a small amount of pulp wood pyrolysis products such as acetic acid, benzaldehyde, and vanillin as a top note. On the other hand, many aromatic compounds that might be produced by pyrolysis of ligneous part were detected from Jinkoh smoke. The odor profiles of Kanankoh and Jinkoh smokes are also discussed

Iwago K., Kodama S., Konishi T., Kiyosawa S., Fujiwara Y., Shimada Y (1987) "The Structure of AH15 & AH18, new bi- and tri-phenyethylchromones from agarwood" *Chem. & Pharm. Bulletin* **35**(11), 4680-4682.

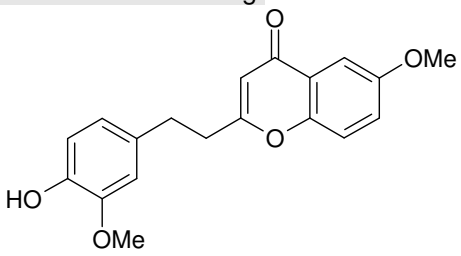
Iwago K., Kakae T., Konishi T., Kiyosawa S., Fujiwara Y., Shimada Y., Miyahara K., Kawasaki T. (1989) "Studies on the Agarwood (Jinko [*Aquilaria*]) VIII. Structures of bi-phenylchromone derivatives" *Chem & Pharm Bulletin* **37**(1), 124-8 and notes.

Jain T.C. & Battacharrya S.C. (1959) "Structure, stereochemistry and absolute configuration of agarol, a new sesquiterpene alcohol from agarwood oil." *Tetrahedron Letters* **1**(9),13-17.

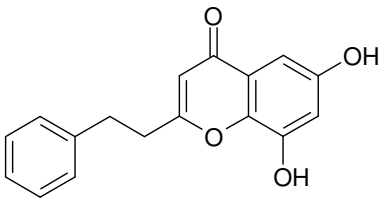


agarol

Konishi T., Konoshima T, Shimada Y, Kiyosawa S (2002) "Six new 2-(2-phenylethyl)chromones from Agarwood." *Chem Pharm Bull* (Tokyo) 2002: **50**(3), 419-422. Abstract: Six new chromones, 6-methoxy-2-[2-(3-methoxy-4-hydroxyphenyl)ethyllchromone (2), 6,8-dihydroxy-2-(2-phenylethyl)chromone (3), 6-hydroxy-2-[2-(4-hydroxyphenyl)ethyl]chromone (4), 6-hydroxy-2-[2-(2-hydroxyphenyl)ethyl]chromone (5), 7-hydroxy-2-(2-phenylethyl)chromone (6), & 6-hydroxy-7-methoxy-2-(2-phenylethyl)chromone (7) were isolated from the ether extract of agarwood in addition to a known compound, 2-(2-phenylethyl)chromone or flidersiachromone (1). Their structures were determined by spectroscopic methods including UV, IR, and NMR spectral data and comparisons with the calculated values using the hydroxyl and methoxyl substituent increments of the chromone ring.



6-methoxy-2-[2-(3-methoxy-4-hydroxyphenyl] ethyl]chromone



6,8-dihydroxy-2-(2-phenylethyl) -chromone

Konishi T., Iwagoe K., Sugimoto A., Kiyosawa S., Fujiwara Y & Shimada Y ((1991) "Studies on Agarwood (jinko). X. Structures of 2-(2-phenylethylcromone derivatives). *Chem. & Pharm. Bulletin* **39**(1) 207-209.

Konishi T., Sugimoto A., Kiyosawa S. & Fujiwara Y. ((1992) ""Studies on Agarwood (jinko). XII. Structures of pentahydroxy-2-(2-phenylethyl)chromone derivatives. *Chem. & Pharm. Bulletin* **40**(3), 778-779.

Konishi Y. Kiyosawa S., Shimada Y. Miyahara K & Kiwasaka T. (1989). "The structure of AH16, a new tetrahydroxy-2-(2-phenylethyl)chromone from agarwood" *Chem. & Pharm. Bulletin* **37**(5), 1428-1430

Lawrence B.M. (1985) "Progress in Essential Oils. Agarwood Oil." *Perf & Flav* **10** Jun/July 1985 pp 27-31.

Lawrence B.M. (1988) “Progress in Essential Oils. Agarwood oil.” *Perf. & Flav.* **23**, Sept/Oct 1988, pp62-66.

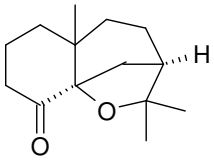
Lawrence B.M. (1998) “Progress in Essential Oils. Agarwood oil.!” *Perfum. Flav* **23**(5), 55-68 (1998).

Lee, M. W., Houghton, P. J., Simmonds, M. S. J., Leon, C., & Kite, G. C. "Authentication of the Chinese drug Agarwood" *J Pharm and Pharmacology British Pharmaceutical Conference 2002* **54**(Supp), 191 Pharmaceutical Press 2002.

Lidong L. & Shuyuan Q. "Triterpenoid from Chinese eaglewood (*Aquilaria sinensis*)" *Chinese Traditional & Herbal Drugs* 2000 **31**(2), 89.

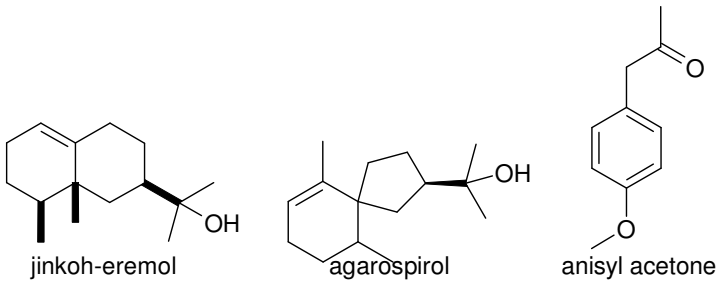
Maheshwari M.L., Jain T.C., Bates RB, Battacharyya S.C. (1963) "Terpenoids XLI. Structure and absolute confiuguration of -agarofuran, -agarofuran and dihydroagarofuran." *Tetrahedron* **19**, 1079-1019. Abstract. In addition to the furanoid compounds reported previously, three more crystalline furanoids of the selinane group have been isolated from agarwood oil, obtained from the fungus infected plant *Aquillaria agallocha* Roxb. The structures and absolute configurations have been determined by their interconversions into the compounds previously reported.

Maheshwari M.L., Varma K.R. & Bhattacharyya S.C. (1963) “Tripenoids XLVII Structure and absolute configuration of nor-ketoagarofuran, 4-hydrodihydroagarofuran, 3,4-didydroxydihydroagarofuran and conversion of beta- and alpha-agarofuran.” *Tetrahedron* **19**, 1519-1525. Abstract. In addition to the furanoid compounds reported previously, three more crystalline furanoids of the selinane group have been isolated from agarwood oil, obtained from the fungus infected plant *Aquillaria agallocha* Roxb. The structures and absolute configurations have been determined by their interconversions into the compounds previously reported.



nor-ketoagarofuran

Meier M., Kohlenberg B., & Braun N. A. "Isolation of anisyl acetone from agarwood Oil" (2003) *JOER* **15**(1), 54-56. Abstract. The essential oil of *Aquilaria agallocha* from Assam, India was analysed using GC/MS. The main constituents were found to be agarospirol (12.1%) and jinkoh-eremol (10.0%). Anisyl acetone was isolated as a minor constituent and fully characterized from a commercial sample of agarwood oil.



jinkoh-eremol agarospirol anisyl acetone

Naf R., Velluza A., Busset N. & Gaudin J.M. (1992) "New nor-sesquiterpenoids with 10-epi-eudesmane skeleton from agarwood (*Aquilaria agallocha* Roxb.)" *Flav. & Frag. J.* **7**(6), 295-298.

Näf R., Velluz A., Busset N., Gaudin, J.-M. (1992) "New nor-sesquiterpenoids with 10-epi-eudesmane skeleton from agarwood (*Aquilaria agallocha* Roxb.)" *Flav & Frag J.* **7**(6), 295-298. Abstract: Six new sesquiterpenoids with the 10-epi-gamma-eudesmol skeleton were prepared

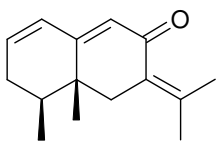
from agarwood oil (*Aquilaria agallocha* Roxb.) (2R,4aS)-2-(4a-methyl-1,2,3,4,4a,5,6,7-octahydro-2-naphthyl)-propan-2-ol, (S)-4a-methyl-2-(1-methylethyl)-3,4,4a,5,6,7-hexahydronaphthalene, (S)-4a-methyl-2-(1-methylethylidene)-1,2,3,4,4a,5,6,7-octahydronaphthalene, (2R,4aS)-4a-methyl-2-(1-methylethenyl)-1,2,3,4,4a,5,6,7-octahydronaphthalene, (1R,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01.6]dodecane and (1R,2R,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01.6]dodecan-2-ol.

Näf R., Valluz A., Thommen W & Baruchli R. (1993) "New Compounds Identified in Agarwood (*Aquilaria agallocha* Roxb.)" *Flav. & Frag J.* **8**(6), 307 -313. Abstract: Four new compounds have been isolated from agarwood oil (*Aquilaria agallocha* Roxb.) and their structures confirmed by synthesis (1R,2R,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01,6]dodecane-2-spiro-2'-oxirane (epoxy-beta-agarofuran, (1S,2S,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01.6]dodecane-2-carbaldehyde, (E)-8,10-undecadien-2-one and 2,t-3-dimethyl-r-2-(3-methyl-2-butenyl)-1-cyclohexanone (absolute configuration unknown). Several of their diastereoisomers, such as (1R,2S,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01.6]dodecane-2-spiro-2'-oxirane, (1S,2R,6S,9R)-6,10,10-trimethyl-11-oxatricyclo[7.2.1.01,6]dodecane-2-carbaldehyde, (Z)-8,10-undecadien-2-one and racemic 2,c-3-dimethyl-r-2-(3-methyl-2-butenyl)-1-cyclohexanone were also synthesised and fully characterised. The 13C NMR data of agarospirol published earlier are corrected. The assignments are fully supported by 1D-INADEQUATE experiments.

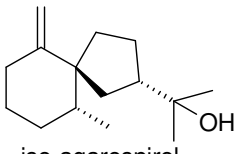
Näf R., Velluz A., Brauchli & Thommen W (1995) “Agarwood oil (*Aquilaria agallocha* Roxb.). Its composition and eight new valencane-, eremophilane-, vetispirane- derivatives.” *Flav. Frag J.* **10**, 147-152 (1995). Abstract: The profile of the total extract of agarwood oil (Aquilaria agallocha Roxb.) is discussed and eight new sesquiterpenoids are presented: two with the eremophilane-skeleton (rel-(2R,8S,8aR)-2-(1,2,3,5,6,7,8,8a-octahydro-8,8adimethyl-2-naphthyl)-prop2-en-1-ol (eremophila-9,11(13)-dien-12-ol) and rel-(3R,7R,9R,10S)-9,10-dimethyl-6-methylene-4-oxatricyclo[7.4.0.03,7]tridec-1-ene, one with the valencane skeleton (rel-(2R,8S,8aR)-2-(1,2,6,7,8,8a-hexahydro-8,8a-dimethyl-2-naphthyl)-propan-2-ol (valenca-1(10),8-dien-11-ol) and four with the vetispirane skeleton (rel-(5R,10R-)-(2-isopropylidene-10-methylspiro[4,5]dec-6-ene-6-carbaldehyde (vetaspira-2(11),6-dien-14-al), rel-(5R,m7R,10R)-2-isopropylidene-10-methyl-6-methylene-spiro[4.5]decan-7-ol (vetaspira-2(11),6(14)-dien-7-ol, rel-(1r,2R)-9-isopropyl-2-methyl-8-oxatricyclo[7.2.1.01,6]doddec-5-ene, (2,14-epoxy-vetispir-6-ene) and rel-(1R,2R)-(9-isopropyl-2-methyl-8-oxatricyclo[7.2.1.01,6]dodeca-4,6-diene (2,14-epoxy-vetaspira-6(14),7-diene.2-(1,2,3,5,6,7,8,8a-octahydro-8,8a-dimethyl-2-naphthyl)-propanal (valenc- or eremophil-9-en-12-al) is tentatively identified.

Nagashima T, Kawasaki I., Yoshida T. Nakanishi T., Yoneda K. & Miura I (1983) "New sesquiterpenoids from Agarwood" *Paper presented at the IXth Intern Essential Oil Congress, Singapore. Essen Oil Tech Paper* **3**, 12-16.

Cropwatch comments: Nagashima *et al*. (1983) found the following compounds in an oil distilled from agarwood collected in Cambodia: alpha-agarofuran, ar-curcumene, nerolidol, agarospirol, benzyl acetone, nor-ketoagarofuran, kusunol, & jinkoh-eremol, as well as characterising new components: dihydrokaranone, karanone, oxo-agoarospirol & iso-agarospirol.



karanone



iso-agarospirol

Nakanishi T., Yamagata E., Yoneda K., & Muira I. (1981) "Jinkohol a prezizaene sesquiterpene alcohol from Agarwood *Aquilaria* sp." *Phytochem* **20**(7), 1597-1600. Abstract: A new tricyclic sesquiterpene, jinkohol, has been isolated from agarwood (*Aquilaria* sp.) which is different from that obtained from *Aquilaria agallocha*. Its structure was shown to be 2-beta-hydroxy-(+)-

prezizane by spectroscopic methods and by chemical transformation. Two kinds of agarwood are readily identified from their sesquiterpene components.

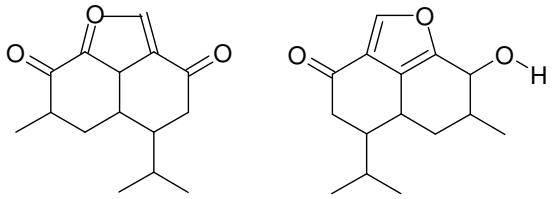
Nakanishi T, Yamagata E. *et al.* (1984) "Three fragrant sesquiterpenes of agarwood" *Phytochemistry* **23**(9), 2066-2067. Abstract: Three fragrant sesquiterpenes have been isolated as major constituents of the wood of *Aquilaria malaccensis* and identified as alpha-agarofuran, (-)-10-epi-eudesmol and oxo-agarospirol.

Nakanishi T., Inada A., Nishi M., Yamagata E. & Yoneda K. (1986) "A new and a known derivatives of 2-(2-phenylethyl)chromone from a kind of agarwood ("kanankoh" in Japanese) originating from *Aquilaria agallocha. Journal of Natural Products* **49**(6),1106-1 108,

Natarajan R.K. & Purushothaman K.K. (1991) Capt. Srinavasa Murti Drug Research Institute (Ayurveda) Arumbakkam, Madras-600 029): "Alkaloids from Agaru" *33rd Indian Pharmaceutical Congress, Jaipur, India Dec 20-22 1981.*

Pakinar S.K. & C.G. Naik (1975) "Stereocemistry of dihydroagarofurans and evidence in support of the structure of 4,11-epoxy-cis-eudesmane" *Tet. Letters* **15**, 1293-1294.

Pant P. & Rastogi R.P. (1980) "Agarol, a new sesquiterpene from *Aquilaria agallocha*" *Phytochemistry* **19**(8), 1869-1870. Abstract. The isolation of two sesquiterpenes, gmelofuran and agarol, from *Aquilaria agallocha*, is described. Gmelofuran has not been previously reported from this genus and the structure of agarol has been elucidated by physical methods and chemical reactions.



gmelofuran agarol

Pramote Triboun (1997) "Analysis and induction of volatile compounds from *Aquilaria crassna* Pierre ex H. Lec. tissue in vitro; Kan wikhro lae kan chaknam sanhomrahoei khong nua-yua ton kritsana nai saphap plotchua." *Summary from Kasetsart Univ., Bangkok (Thailand). Graduate School.* Abstract. Agarwood (*Aquilaria crassna* Pierre ex H. Lec.) oil obtained by water-steam distillation from Soi Na Na Bangkok and Nakornnayok province and by diethyl ether extract from agarwood tissue (in vitro culture) were analysed by Gas chromatography-Mass spectrometry. The major constituents of agarwood oil were in sesquiterpene group especially agarospirol. However, these volatile compounds were not detected in agarwood tissue extract. Addition of linalool, abscisic acid, gibberellic acid, ethephon, potassium dihydrogen phosphate, sucrose or agarwood oil at various concentrations to Murashige and Skoog media affected growth and development of agarwood tissue. Only abscisic acid and ethephon tissue caused differentiation similar to that induced by agarwood oil. The differentiation was characterised by swollen nodes, constriction of internodes and yellowish leaves.

Qi S-Y, Bi-Yau L., Liang-Feng Z. & Bao-Ling Li "Formation of oxo-agarospirol in *Aquliaria sinensis*." *Plant. Phys. Commun.* **28**, 336-339.

Saufi A, von Heimendahl CB, Alfermann AW, Fuss E. (2008) "Stereochemistry of lignans in *Phaleria macrocarpa* (Scheff.) Boerl." *Z Naturforsch* [C]. **63**(1-2), 13-16. Abstract. *Phaleria macrocarpa* (Scheff.) Boerl., a member of the Thymelaeaceae, is traditionally used in Indonesia as medicinal plant against cancer. In this context, we isolated the lignans pinoresinol, lariciresinol and matairesinol from different parts of this plant. The enantiomeric composition of these lignans was determined by chiral column analysis. Pinoresinol and lariciresinol were mixtures of both

enantiomers with (79 +/- 4)% and (55 +/- 6)% enantiomeric excess for the (-)-enantiomers, respectively, whereas matairesinol was found as pure (+)-enantiomer.

Schun Y. & Cordell G.A. (1985) "Studies in the Thymelaeaceae III. Constituents of *Gyrinops walla*.' *Journal of Natural Products* **48**(4), 684.

Shankaranarayana K.H., Parthasarathi K. & Rai S.N. (1986) "HAWS & HEBS – two new essential oils from spent Agarwood and *Bursera* Husk" *Perf. & Flav.* **11**. Oct/Nov 1986 p93-95.

Shimada, Y. Tominaga, T., Konishi T., and Kiyosawa, S. (1982). "Studies on the Agarwood (Jinko) I – Structures of 2-(2-Phenylethyl) chromone derivatives." *Chem. Pharm. Bull.* **30** (10) 3791-3795.

Shimada, Y., Tominaga, T., and Kiyosawa, S., 1985. *Studies on the Agarwood (Jinko) IV – Correlation between the Grading of Agarwood on the Market and the Chromone derivatives. Yakugaku Zasshi*, **106**(5) 391-397.

Talukdar A., Ahmed G.U. & Dutta S.K. (2002) "In vitro produced agaroil from callus culture of *Aquilaria agallocha* Roxb. and analysis of its chemical constituents by GC/MS. *Koryo* **46**, 350 Abstract. Callus was induced from leaf explants of Aquilaria agallocha Roxb. (Thymeliaceae) in MS medium supplemented with 2,4-D (6mg/l) and kn. (2mg/l). However callus could also be induced in WPM and B5 media with supplementation of 2,4-D (0.5-8.0mg/l) and kn (2mg/l). Callus could also be induced from stem and shoot tip as explants. Six months old brown mature callus was distilled by modified stahl apparatus to investigate the synthesis of essential oil in cultured tissue. The distillate so obtained was vacuum evaporated under reduced pressure, and the extract analyzed by GC/MS using a fused silica capillary column (25*0.20*0.33) to study the organic chemical constituents. Chemical investigations showed some variations in the quality of the oil produced by callus, when compared with the oil obtained by hydrodistillation of fungal infected agarwood. GC/MS analysis has shown the presence of about 32 different compounds comprising of furano-monoterpenoids, acids, alcohols and aldehydes, out of which 15 compounds could be identified. About 30% of the identified compounds showed similarity with the agarwood oil sample. (author abst.)

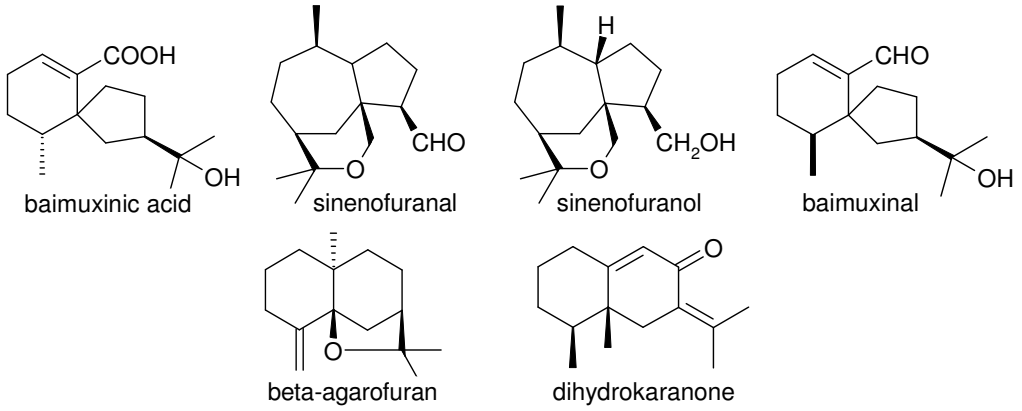
Tamuli P., Boruah P. & Samanta, R. (2004) "Biochemical changes in agarwood tree (*Aquilaria malaccensis* Lamk.) during pathogenesis." *Journal of Spices and Aromatic Crops* **13**(2), 87-91. Abstract. The changes in sugar, ascorbic acid, phenol and protein contents of *A. malaccensis* were investigated after inoculation with *Chaetomium globosum* and *Fusarium oxysporum*. In healthy trees, the biochemical constituents increased. In infected trees, a decrease in the biochemical constituents was observed after inoculation with the fungi.

Tamuli P., Boruah P., Nath S.C. & Ledercq P. (2005) "Essential oil of Eaglewood Tree: a product of pathogenisis" *J. Essent Oil. Res* **17**, 601-604. Abstract: The essential oil of the Eaglewood tree (*Aquilaria agallocha* Roxb.) has been considered to be a pathological product. An investigation was carried out to study the difference in composition of oils obtained from healthy, naturally infected and artifically inoculated eaglewood using GC and GC/MS analyses. This investigation shows a marked difference in the oil compositions among the treatments witrh regards to their quality. Valerianol (3.0%) and tetradecanoic acid (7.1%) contents were recorded higher in the oils of naturally infected plants than in that of healthy ones (0.1% and 6.9% respectively). Pentedecanoic acid was totally absent in the oils of healthy (.plants/trees?), whereas it was found in a greater amount (6.8%) in the oil of naturally infected plants. In contrast dodecanoic acid (3.1%), pentedecanoic acid (6.2%), hexadecanoic acid (31.5%) and octadecanoic acid were found in the oils of healthy plants, while the oils obtained from naturally infected plants contained lower amounts of these components (2.3%, 4.8%, 20.0% and 1.0% respectively). The oils obtained from the inoculated plants showed almost similar distribution of the components with healthy plants.

Thomas A.F. & Ozianne M. (1976) "The stereochemistry of the dihydroagofurans" *Tert. Lett.* **20**, 1717-1718.

Varma K.R., Maheshwari M.L. & Bhattacharyya S.C. (1965) "Terpenoids LXII. The constitution of agarospirol, a sesquiterpenoid with a new skeleton." *Tetrahedron* **21**, 115-138. Abstract. Degradative studies and physical measurements supported by an unambiguous synthesis of the derived ketone (XVa) have led to the assignment of a novel spiro-skeleton to agarospirol (Ia), a sesquiterpene alcohol isolated from the essential oil of infected agarwood (*Aquilaria agallocha* Roxb.). The corresponding carbon skeleton (VI) has been named agarospirane. Agarospirol is the second spiro-terpenoid to be isolated from Nature. The most probable stereochemistry of agarospirol appears to be as in XXXIX.

Xu J-F., Zhu L-F., Lu B-Y. & Liu C-T. (1988) "Study on chemical constituents of *Aquilaria sinensis* (Lour) Gilg." *Zhiwu Xuebo* **30**, 635-638.
Cropwatch Comments: Six compounds characterized in Chinese agarwood illustrated below:



Yagura T., Shibayama N., Ito M., Kiuchi F. & Honda G. (2005) "Three novel diepoxy tetrahydrochromones from agarwood artificially wounded by intentional wounding" *Tetrahedron Letters* **46**(25), 4395-4398. Abstract: Three novel diepoxy tetrahydrochromones, oxidoagarochromones A (1), B(2) & C(3) were isolated from agarwood artificially produced by intentional wounding of *A. crassna*. Inductive production of these three compounds was also confirmed at the early stage of wounding in *A. sinensis* and *A. crassna*. These diepoxy tetrahydrochromones would play an important role in the understanding the biosynthesis of chromone derivatives in agarwood.

Yagura T., Ito M., Kiuchi F., Honda G. & Shimada Y. (2003) "Four new 2-(2-phenylethyl)chromone derivatives from the withered wood of *Aquilaria sinensis*." *Chem Pharm Bull* **51**(5), 560-564. Abstract: Four new chromone derivatives, 5-hydroxy-6-methoxy-2-(2-phenylethyl)chromone, 6-hydroxy-2-(2-hydroxy-2-phenylethyl)chromone, 8-chloro-2-(2-phenylethyl)-5,6,7-trihydroxy-5,6,7,8-tetrahydrochromone, 6,7-dihydroxy-2-(2-phenylethyl)-5,6,7,8-tetrahydrochromone were isolated from the methanol extract of withered wood of *Aquilaria sinensis*, together with seven known constituents of agarwood.

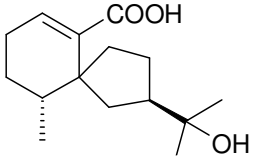
Yamamoto Koryo K.K. "Incense containing chromone derivatives isolated from *Aquilaria agalloca."* Patent: Japan Kokari Tokkyo Koho JP84106414; JP 59106414 Date: 840620 Application: JP82217299 (821210).

Yang J.S., Wang Y.L., Su Y.L. (1989) "[Studies on the chemical constituents of *Aquilaria sinensis* (Lour.) Gilg. IV. Isolation and characterization of 2-(2-phenylethyl)chromone derivatives]" *Yao Xue Xue Bao* **24**(9):678-83. Abstract: Six chromone derivatives were isolated from the ether soluble fraction of the alcoholic extract of *Aquilaria sinensis* (Lour.) Gilg. (Thymeleaceae) by silica gel chromatography. On the basis of spectrometric data (UV, IR, 1HNMR and 13CNMR as well as

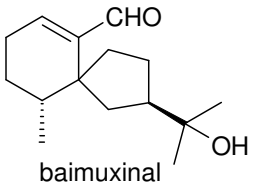
MS) and chemical synthesis one of them was found to be a new chromone, 6-hydroxy-2-[2-(4'-methoxylphenyl)ethyl] chromone(VI) and the other five known chromones are 2-(2-phenylethyl)chromone(I), 6-methoxy-2-(2-phenylethyl)chromone (II), 6.7-dimethoxy-2-(2-phenylethyl)chromone(III), 6-methoxy-2[2-(3'-methoxyphenyl)ethyl]chromone(IV) and 6-hydroxy-2-(2-phenylethyl) chromone(V). These compounds were obtained for the first time from this plant.

Yang J.S., Wang Y.L. & Su Y.L. (1990) "[Studies on the chemical constituents of *Aquilaria sinensis* (Lour.) Gilg. V. Isolation and characterization of three 2-(2-phenylethyl) chromone derivatives]" *Yao Xue Xue Bao* **25**(3),186-90. Abstract: Three 2-(2-phenylethyl) chromone derivatives were isolated from the ethyl acetate soluble fraction of the alcoholic extract of *Aquilaria sinensis* (Lous.) Gilg. (Thymeleaceae) by silica gel chromatography. Based on spectral data (UV, IR, 1HNMR, 13CNMR and MS) two of them are new compounds and their structures were identified as 5,8-dihydroxy-2-(2-p-methoxyphenylethyl) chromone (2) and 6,7-dimethoxy-2-(2-p-methoxyphenylethyl) chromone (3). The known compound isolated for the first time from this plant, was identified as ,8-dihydroxy-2-(2-phenylethyl)-chromone (1).

Yang J.S. & Chen Y.W. (1983) "[Studies on the constituents of *Aquilaria sinensis* (Lour.) Gilg. I. Isolation and structure elucidation of two new sesquiterpenes, baimuxinic acid and baimuxinal] *Yao Xue Xue Bao* **18**(3),191-8.

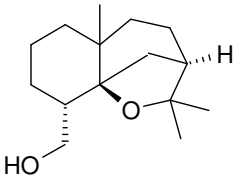


baimuxinic acid

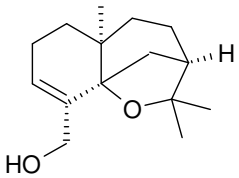


baimuxinal

Yang J.S. & Chen Y.W. (1986) "[Studies on the chemical constituents of *Aquilaria sinensis* (Lour.) Gilg. II. Isolation and structure of baimuxinol and dehydrobaimuxinol]" *Yao Xue Xue Bao* **21**(7), 516-20.



baimuxinol



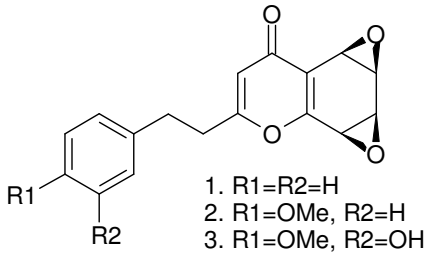
dehydrobaimuxinol

Yang J.S., Wang Y.L., Su Y.L., He C.H. & Zheng Q.T., Yang J. (1989) [Studies on the chemical constituents of *Aquilaria sinensis* (Lour) Gilg. III. Elucidation of the structure of isobaimuxinol and isolation and identification of the constituents of lower boiling fraction of the volatile oil] *Yao Xue Xue Bao*. **24**(4), 264-8. Abstract: A new sesquiterpenoid, named isobaimuxinol, C15H26O2, mp 73-75 degrees C, [a]D12-68(0) (c 0.10, CHCl3), was isolated from the volatile oil of *Aquilaria sinensis* (Lour), Gilg. (Thymeleaceae). Based on spectral (IR, 1H-NMR, 13C-NMR and 2D-NMR as well as MS) analysis its structure was identified as isobaimuxinol. The relative stereochemistry of isobaimuxinol was determined by X-ray crystallograhy. In addition, four known compounds, benzylacetone, p-methoxybenzylacetone, anisic acid and beta-agarofuran were isolated and identified from the lower boiling fraction of the volatile oil of this plant. These compounds were obtained for the first time from this plant.

Yagura T., Ito M., Kiuchi F., Honda G. & Shimada, Y., (2003). "Four new 2-(2-Phenylethyl) chromone derivatives from withered wood of *Aquilaria sinensis." Chem. Pharm. Bull.* **51** (5) 560-564.

Yagura T., Shibayama N., Ito M., Kiuchi F. & Honda G. (2005) "Three novel diepoxy tetrahydrochromones from agarwood artificially produced by intentional wounding." *Tetrahedron*

Letters **46**(25), 4395-4398. Abstract. Three novel diepoxy tetrahydrochromones, oxidoagarochromones A (1), B (2), and C (3), were isolated from agarwood artificially produced by intentional wounding of *Aquilaria crassna*. Inductive production of these compounds was also confirmed at the early stage of wounding in *A. sinensis* and *A. crassna*. These diepoxy tetrahydrochromones would play an important role in understanding the biosynthesis of chromone derivatives in agarwood. Graphical abstract. Three novel diepoxy tetrahydrochromones, oxidoagarochromones A (1), B (2), and C (3), were isolated from intentionally wounded agarwood and they are considered to be produced at the early stage of agarwood formation.



1. R1=R2=H
2. R1=OMe, R2=H
3. R1=OMe, R2=OH

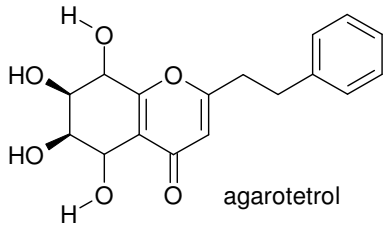
Yoneda K., Yamagata E., Nakanishi T., Nagashima T., Kawasaki I., Yoshida T. & Mo Yoneda K. (1984) "Sesquiterpenoids in two different kinds of agarwood" *Phytochem* **23**(9), 2068-2069. Abstract. Sesquiterpenoids of an agarwood originating from *Aquilaria agallocha* and the other kind of agarwood (*Aquilaria* sp. probably *A. malaccensis*) were investigated by a combination of GLC and GC/MS. The differences in sesquiterpene composition between the two kinds of agarwood are discussed." ***Cropwatch comments***: Yoneda *et al*. (1984) were able to list the major sesquiterpenes of agarwood from type A and type B agarwoods imported from Indonesia and Vietnam through Singapore. *A. agallocha* (agawood type A) was found to contain □-agarofuran 0.6%, nor-ketoagarofuran 0.6%, agarspirol 4.7%, jinko-eremol 4.0%, kusunol 2.9%, dihydrokaranone 2.4%, and oxo-agarospirol 5.8%. In type B agarwood the following compounds were identified □-agarofuran, (-)-10-epi-□-eudesmol 6.2%, agarospirol 7.2%, jinkohol 5.2%, jinko-eremol 3.7%, kusunol 3.4%, jinkohol II 5.6%, and oxo-agarospirol 3.1%. From their findings the authors concluded that type A wood exclusively contains nor-ketoagarofuran and dihydrokaranone, but does not contain (-)-10-epi-gamma-eudesmol, jinkohol and jinkohol II, findings which might be used to distinguish the products.

Yoneda K. (1998). *On the research on Agarwood – the chemical components and the evaluation with their analysis. Koryo* No. **200**.p121-126. Abstract. Agarwood is the most famous fragrance in Japan. After our chemical researches, 9 sesquiterpenoids which were main fragrant components of agarwood are separated. 4 were new compounds and 5 were new separated compounds from agarwood. (Fig. 1). After the Chemical analysis with 9 sesquiterpenoids, agarwoods from southeast Asia will be divided into 6 groups. One of the most gracious group is kyara and its group was separated from agarwood and its group was established from 15 century. On the temporary market of agarwood, the analytical data said that we cannot find any contamination in Kyara with agarwood. (author abst.)

Yoneda K., Yamagata E. , Sugimoto Y. & Nakanishi T (1986) " Pharmocognostical studies on the crude drug of "agarwood" (I): comparison of constituents of essential oil from agarwood by means of GLC and GC-MS." *Shoyakugaku Zasshi* **40**(3):252–258.

Yoneda K., Yamagata E. & Mizuno M (1986) "Pharmocognostical studies on the crude drug of "agarwood" (II): on Chinese agarwood." *Shoyakugaku Zasshi* **40**(3), 259–265.

Yoshii E., Koizuma T. & Oribe T. (1978) "The structure of Agarotetrol: A novel high oxygenated chromone from Agarwood Jinko" *Tetrahedr Letters* **41**, 3921-3924.



agarotetrol

Yusoff N.H., Salleh M.M., Yahaya M. & Awang A.R. (2006) "The use of photoluminescence spectra of TiO2 nanoparticles coated with porphyrin dye thin film for grading agarwood oil." *Semiconductor Electronics ICSE 2006. IEEE International Conference 2006 Kuala Lumpur* Abstract. This paper explores the possibility using nanostructure thin film of TiO2 nanoparticles coated with porphyrin dye based on fluorescence technique to grade agarwood oil. The sensing material was prepared using synthesized of TiO2 nanoparticles colloid is in a sol-gel form. Then the nanoparticles were coated with dye, Iron (III) meso tetraphenyl porphine chloride. The coated nanoparticles were deposited on quartz substrate using self- assembly through dip coating technique. The sensing properties of the thin film toward five grades of agarwood oil were studied using luminescence spectrometer. It was found that the thin film produced different emission spectra peaks for different grades of agarwood oil. Hence the thin film potentially be use as sensing material for grading agarwood oil and others nature product for the future.

Agarwood - Biotechnological Production

Ito M., Okimoto K-i., Yagura T., Honda G *et al*. (2005) "Induction of sesquiterpenoid production by methyl jasmonate in *Aquilaria sinensis* cell suspension culture" *JOER* Mar/Aril 2005. Abstract. A suspension cell culture was established from *Aquilaria sinensis*, a timber species producing fragrant woody material called "Agarwood." Methyl jasmonate was added to this culture in order to induce production of fragrant compounds. Cells were harvested after seven days of incubation and subjected to solid phase micro-extraction to produce an extract that was analyzed by GC/MS. Three peaks appeared on GC and were identified as a-guaiene, d-guaiene (= 1(10),11-guaiadiene), and a-humulene based on their mass fragmentation patterns and ^sup 13^C-NMR data. The production of the guaiene derivatives and a-humulene showed different kinetics, which may mean they are the products of different induced biosynthetic enzymes.

Jalaluddin M (1977) "A useful pathological condition of wood" *Economic Botany* **31**, 222-224. Abstract: A fungus known as *Cytosphaera manganiferae* Died. Was isolated for the first time from the diseased tissues of standing trees of *Aquilaria agallocha* Roxb. Irregular patches of diseased wood, a result of natural infection, are found in the trunks of standing *A. agallocha* trees, which are of great economic importance. A fragrant perfume known locally as 'attar' is obtained from the diseased wood by steam distillation. Incomplete or partially diseased wood is employed in the preparation of a joss-stick locally known as 'agarbatee' which gives out fragrant fumes on burning. The fungus colonised wood blocks of *A. agallocha* when these were inoculated artificially. There is a possibility of commercial exploitation for the production of diseased wood by artificial infection.

van Minh T. (2005) "Application of tissue culture techniques in woody species conservation. Improvement and development in Vietnam: Agarwood (*Aquilaria crassna* Pierre ex LeComte) via shoot-tip culture, *Acta Hort* (ISHS) **692**, 37-42. Abstract. *Aquilaria crassa* (agarwood), a Vietnamese forest tree, was micropropagated using shoot explants from 20-year old trees known to produce the valuable exudates ‘tok’. Either shoot tips or internodes could be used for the initial explants, but in subcultures best results were obtained from internodes. Woody Plant Medium was a better basal medium than Murashige and Skoog, and for initial shoot induction BA at 1mg/l and coconut water at 10% was used. For subcultures, BA at 0.1mg/l, NAA 0.1mg/l and coconut water at 10% gave highest shoot multiplication. A low level of rooting was obtained using either IBA or NAA at 0.3 mg/l. Plants transferred to the field grew to 2m after 18 months and had normal morphology.

Mohammed C. (2003). “The artificial stimulation of resin formation in the stems or branches of gaharu producing trees: *Aquilaria, Aetocylon, Gonystylus* and *Gyrinops*.” Proposal submitted to Australian Centre for International Agricultural Research by CSIRO Forestry and Forest Products.

Mondai, K. & Chatterton, P. (2001)/. “14 steps for sustainable gaharu harvest.” Unpublished material presented to the 2nd Papua New Guinea Gaharu Inter Agency Committee Meeting, 2001 .Port Moresby. WWF, Madang.

Panikar S.K. & Dhavlikar R.S. (1975) "Microbial transformation of terpenoids: a microbial preparation of dihydro- -agarofuran from valencene" *Chem. Ind.* 432-433.

Pojangaroon S. & Kaewrak C. (2005) “Mechanical methods to stimulate aloes-wood formation in *Aquilaria crassna* Pierre ex H.Lec (Kritsana) trees.” *Acta Horticulturae* **676**, 161-166. Abstract: The efficacy of mechanical methods of stimulating wood formation in *A. crassna* trees was determined in a field experiment conducted in Thailand between Feb 2001 to Oct 2002. The treatment comprised wounding using narrow (T1) and wide (T2) chisels making holes using screws that are 0.40 (T3), 0.55 (T4), 1.11 (T5, and 1.27 cm. In diameter(T6); bark removal using hatchets (T7); hammering nails that are 2.54 (T8), 5.08 (T9), 7.62 (T10), 10.16 (T 11) and 12.70 cm. long (T12); and hammer beating the trunk (T13). Holes made by screws, wounds inflicted by chisels and bark removal caused a dark yellow-brown discolouration of the trunk near the injury, whereas hammering nails into the trunk caused a dark brown-black discolouration. The larger the objects used to wound the trunk, the wider the width of the discolouration rings. The rate of discolouration ring formation was 3 times higher during the rainy season compared to the dry season. Then most suitable method for inducing formation of aloes wood was through the use of 1.27 cm. wide screws which gave the widest discolouration ring and pale specific aromatic kritsana scent by burning. Wood samples gave very low essential oil yield.

Qi S..-Y. "*Aquilaria* Species: In vitro culture and the production of Eaglewood (Agarwood) (1995)" *Biotechnology in Agriculture & Forestry - Medical and Aromatic Plants VIII* **33,** 36-46.

Qi S., Lin L. & Ye Q. (1998) " Benzylacetone in Agarwood and Its biotransformation by *Melanotus flavolivens*" *Chin. J. of Biotech*. -Chin Edn- **14**(4), 464-467.

Qi S.-Y, & Sethi KL (1989) "Accumulation of Secondary Metabolites in Cell Suspension Culture of *Aquilaria sinensis* (Lour.) Gilg. (Thymelaeaceae). In Bhattacharyya SC (ed.) Sen N (ed.) *Proceedings of the 11th Internat Congress on Essential Oils, Fragr & Flavours New Delhi India 12-16 Nov. 1989* Vol **3**, 1-4.

Qi S-Y., Meng-Ling He., Lin L-D., Chuan-Hai Zhang C-H., Hu L-J. & Zhang H-Z. (2005) "Production of 2-(2-phenylethyl) chromones in cell suspension cultures of *Aquilaria sinensis*." *Plant Cell, Tissue and Organ Culture* **83**(2), 217-221. Abstract. 2-(2-Phenylethyl) chromones are the major constituents responsible for the quality of agarwood, which is one of the most valuable non-timber products used as incenses, perfumes, traditional medicines and other products. In this study, cell suspension culture of *Aquilaria sinensis* (Lour) Gilg was used to monitor the eliciting effects of crude fungal extracts on cell growth and chromones production. Crude extracts of *Melanotus flavolivens* (B. etc) Sing. prepared with different solvents were used to elicit the production of 2-(2-phenylethyl) chromones in cell suspension cultures of *A. sinensis*. Four 2-(2-phenylethyl) chromones, 6,7-dimethoxy-2-(2-phenylethyl) chromone (1), 6,7-dimethoxy-2-[2-(4′-methoxyphenyl)ethyl] chromone (2), 6-methoxy-2-[2-(4′-methoxyphenyl)ethyl] chromone (3) and 6-methoxy-2-(2-phenylethyl) chromone (4), were detected by LC–MS in the cell suspension culture of *A. sinensis* elicited with crude extracts of *M. flavolivens*. Three hundred and seventy eight, 196 and 31 μg g−1 DW of 2-(2-phenylethyl) chromones were obtained in the cell cultures induced by water extracts, 50 and 95% ethanol extracts of *M. flavolivens*, respectively. The

results show that water-soluble materials in the crude extracts are the main components inducing the production of 2-(2-phenylethyl) chromones in the cell cultures.

Rahman M.A. & Basak A.C. (1980) "Agar production in agar trees by artificial inoculation and wounding" *Bano Bigan Patrika* **9**(1&2) 86-93. Abstract. Experiments to determine the role of wounding and fungal infection in the formation of the aromatic base, agar, in the wood of the Agar tree (*Aquilaria agallocha* Roxb) were conducted. Inoculation without wounding using three fungal isolates from agar, as well as, wounding without inoculant, produced colour changes and oleoresin deposits in the host characteristic of agar. It was inferred that formation of agar did not depend on the activity of a special fungus, as was previously believed, but is a general reaction of the host to injury or invasion. The possibility of the development of techniques for the commercial induction of agar is also discussed.

Rahman, M. A. & Khisa K.S.. (1984)." Agar production in agar tree by artificial inoculation and wounding. Part II. Further evidence in favour of agar formation." *Bano Biggyan Patrika* **13**, 57–63.

Agarwood Cultivation.

Baruah J.N., Mathur R.K., Jain S.M. & Kataky J.C.S. (1982) "Agarwood." In *Cultivation and Utilisation of Aromatic Plants* Atal C.K. & Kapur B.M. eds. CSIR Jammu-Tawi, India pp 662-667.

Battacharyya B., Datta A., Barauah H.K. (1952) "On the formation and development of Agaru in *A. agallocha*" *Sci & Cult* **18**(5), 240-243.

Beniwal B.S. (1989) "Silvical characteristics of *Aquilaria agallocha* Roxb." *Indian Forester* 1**15**(1), 17-21.

Bhaskar V. (1984) "Seed germination of Agarwood tree (*Aquilaria agallocha* Roxb.) under Bangalore Conditions." *Myforest* **20**(1), 2-3.

Blanchette R.A., Heuveling Van Beek H. (2002) *Cultivated Agarwood*. Eu Patent No WO02094002 pub. date 2001-11-28. Abstract: The present invention provideds agarwood and/or agarwood resin from cultivated trees, and methods of generating agarwood and/or agarwood resin in cultivated trees.

Bolier B. (2004). "What about agarwood in the Philippines? An inventory and research on Philippine agarwood producing trees and its possible harvest. *Unpublished research report, Department of Anthropology, University of Amsterdam.*

Boruah J.N., Mathur R.K., Jain S.M. & Kataky J.C.S. (1982) "Agarwood." In CK Atal & BM Kapur (eds) *Cultivation and Utilisation of Aromatic Plants* RRL Jammu-Tawi, Atal 0662-667.

Bose S.R. (1934) "The Nature of Agar formation" *Sci & Cult* **4**(2), 89-91.

Bose S.R. (1939) "Enzymes of wood-rotting fungi" *Ergeb. Enzymforsch* **8**, 267-276

Broad S. (1995) "Agarwood Harvesting in Vietnam." *TRAFFIC Bulletin- Wildlife Trade Monitoring Unit 1995* **15**(2), 96 Traffic International.

Chang Y.S., Nor-Azah M.A. Abu-Said A., Lok E.H., Reader S., Spiers A. (2002) "Gaharu" *FRIM - Technical Information Forest Research Institute Malaysia No 69.* pub. Forest Research Instit. Malaysia, Kuala Lumpur, Malaysia.

Chung, R. C. K. & Purawaningsih (1999.) *Aquilaria malaccensis* Lamk. in L. Oyen, and X. D. Nguyen, editors. *Plant resources of South-East Asia No. 19: essential-oil plants*. Backhuys Publishers, Leiden, the Netherlands pp 64-67..

CITES (2006) "Final report of CITES-financed pilot project: Search for DNA markers to discriminate cultivated from wild gaharu (agarwood)." Presented at 16th Meeting of Plants Committee Lima (Peru) 3-8 July 2006. Report prepared by Eurlings MCM & Gravendeel B. under contract with CITES Secretariat.

Gerber, N. 2003. “Capturing the Resource Rent. An economic assessment of the gaharu (gaharu/eaglewood) trade in Papua New Guinea.”. A TRAFFIC Report in conjunction with WWF South Pacific Program.

Gunn, B., Stevens, P., Singadan, M., Sunari, L. and Chatterton, P. (2004) “Eaglewood in New Guinea”. Resource Management in Asia-Pacific Working Paper No.51, Resource Management in Asia-Pacific Program, Research School of Pacific and Asian Studies, Australian National University.

Hai L.E., & Yahya A.Z. (1996) "The growth performance of plantation grown *Aquilaria malaccensis* in Peninsula Malaya." *J. of Tropical Forest Science* **8**(4), 573-575.

Hai, L.E., Shyun C.Y. & Yussof A.M. (1999) "Early survival and growth in field trials of *Aquilaria malaccensis* (karas) and *Azadirachta excelsa* (sentang)" *J. of Tropical Forest Science* **11**(4), 852-854.

Hasnida, H. N., M.Y. Aziah, M. Salbiah, Z. Fadhilah, I. Haliza & H.J. M. Azmy (2001). "Multiplication of shoots from in vitro germinated seedlings of *Eurycoma longifolia* and *Aquilaria malaccensis*." pp 269-276 in *Tropical Forestry research in the new millennium: meeting the challenges. Proceedings of the International Conference on Forestry and Forest Products Research, 1-3 October 2001, Kuala Lumpur, Malaysia*.

Itoh T., Tabata Y., Widjaja E., Mulyaningsih T., Parman, Wiriadinata H. &, Mandang Y. (2005) "Structure and artificial induction of Aloe wood" The Fifth Pacific Regional Wood Anatomy *Conference. Abstracts from the Meeting of the IAWA Pacific Regional Group & IUFO S 5.01 (Wood Quality), Jakarta Indonesia 9-14 Sept. 2002*. *IAWA Journal* 2002 **23**(4), 466-7.

He M.L. Qi S-Y & Hu L-J. (2005) “Rapid in vitro propagation of medicinally important *Aquilaria agallocha*.” *J. of Zhejiang University Science* **6B**(8), 849-852. Abstract: *A. agallocha* [*A. malaccensis*] can produce fragrant agarwood used for incense, traditional medicine & other products. An efficient plant regeneration system was established via organogenesis from shoots developed from seedlings of *Aquilaria agallocha*. Shoots generated many buds on MS medium supplemented with 1.3 micromol/L. BA (6-benzylaminopurine) in the first 7 weeks, and the buds elongated on MS medium with 1.3 micrmol/L. BA (benzyladenine) + 0.5 micromol/L. NAA (naphthaleneacetic acid) in another 7 weeks, 2.3 shoots 2cm. In length per explant were obtained within 14 weeks. Plantlets were rooted on ½ MS medium after being immersed in 5 micromol/L. NAA for 48 h. 96.7% of the roots grew well 2 weeks later. All plantlets that survived acclimatisation grew well in the pots.

Ismail P., Shamsudin I., Abdul Rahman k. & Hashim W.S. (2007) "Planting of *Gonystylus bancanus* in non-peat swamp area." *J. Trop Forest Science* 2007, Forest Res Inst. Malaysia.

Kevan P.G. & Gaskell B.H. (1986) "The awkward seeds of *Gonystylus macrophyllus* (Thymelaeaceae) and their disperal by the bat *Rousettus celebensis* in Sulawesi, Indonesia.” *Biotropica* **18**(1), 76-78.

Nakashima E.M.N., Nguyen M.T. Nguyen M.T. Le Tran Q. & Kadota S. (2005) “Field survey of agarwood cultivation at Phu Quoc Island in Vietnam”. *J. Trad. Med.,* **22**, 296-300. Abstract. Agarwood is one of most valuable minor forest products of tropical Southeast Asia forests. In Vietnam, considered as rich source of high quality product, agarwood is collected from heartwood of *Aquilaria crassna* (Thymelaeaceae). Continuing the survey of agarwood in Vietnam, it was

carried out on plantations at Phu Quoc Island, and information about cultivation of agarwood was gathered from interview with local people. The results showed that cultivation of agarwood by islanders is increasing every year. Local plantations are based on seeds, seedlings and young Aquilaria trees, which grows together with other crops, for a future profit. The promotion and development of agarwood plantations would be an initiative to preserve natural *Aquilaria* trees, as well as supply the high demand for agarwood in world market.

Quan Le Tran, Qui Kim Tran, K. Kouda, N. T. Nguyen, Y. Maruyama, I. Saiki, and S. Kadota. (2003). "A survey on agarwood in Vietnam." *Journal of Traditional Medicine* **20**(3):124–131. Abstract. Agarwood is a one of the most valuable minor forest products of the Southeast Asian tropical forests. In Vietnam agarwood is produced from the heartwood of rarely available natural *Aquilaria crassna* trees (Thymelaeaceae). In our field work in Vietnam, a natural *A. crassna* was found in Khanh Hoa Province. Information on agarwood exploitation and production were also gathered by interviewing the local people. The result showed that part of the local people earn their living by dealing with agarwood, but due to over exploitation the natural resource for this valuable plant has declined dramatically in the past decades, while the demand for the resource remains constant or even increases. The cultivation of *A. crassna* has been started in several places in the country as an initiative for conserving this endangered but economically important plant species.

Soehartono, T. Newton, A. C. (2001) "Reproductive ecology of *Aquilaria* spp. in Indonesia" *Forest Ecology & Management* **152**(1-3), 59-71. Abstract. *Aquilaria* spp. (Thymelaeaceae) are the principal source of Gaharu, a valuable resin, yet information about their reproductive ecology is almost entirely lacking. Individuals of six species (*A. beccariana*, *A. crasna*, *A. filaria*, *A. hirta*, *A. malaccensis* and *A. microcarpa*) in cultivation in Indonesia were investigated to assess reproductive phenology, pollination, seed production and germination. Seed production and seedling dispersion were also assessed in natural populations of *A. beccariana*, *A. malaccensis* and *A. microcarpa* in Kalimantan. Most of the selected trees flowered during the dry season, fruits requiring between 36 and 72 days to develop, depending on the species. Twenty different species of insect were recorded visiting flowering trees. The probability of flowers developing into fruit varied between species from 0.04 to 0.43, although flowers from which pollinators were excluded never produced fruit. Seed production of *A. malaccensis* and *A. microcarpa* peaked at a dbh of approximately 40 and 50 cm, respectively, individual trees producing up to 19,000 seeds in a single season. Germination under nursery conditions was initiated 7–15 days after sowing; seeds of A. crasna had the highest probability of germination success (92%) whereas those of A. filaria had the lowest (53%). In natural forest, most seedlings (>65%) occurred within 5 m of an adult tree, suggesting limited dispersal. These results indicate that Aquilaria spp. have high reproductive potential, but suggest that seed dispersal might be limited in natural forests. The implications of these results for the management of *Aquilaria* spp. are discussed.

Tabata,Y., Widjaja E., Mulyaningsih T., Parman I., Wiriadinata H., Mandang Y.I. & T. Itoh. (2003). "Structural survey and artificial induction of aloeswood." *Wood Research* **90**, 11–12. Abstract: A structural survey of aloeswood tissue was done to investigate the pattern and variation of resin deposition in aloeswood, and to know its standard features. Artificial induction method of aloeswood was also conducted. The study was conducted in two plantation sites, Matarum on Lombok island (*Gyrinops versteeghii*) and Pekanbaru in Sumatra island, Indonesia (*Aquilaria*), and the stems were inoculated with *Fusarium*. The results showed that there were many types of colour and shape of resin on aloeswood, but many have some injured parts. Resin deposition occurs around the drilled site, above the term of treatment or differences of wood species and fungi. Resin deposition also occurred not only in fungi-inoculated but also in control trees. There were no differences observed in the three treatment terms (half year, one year, one and half year).

Tiengtum P. & Prutpongse P. (1995) "In vitro culture of agarwood trees (*Aquilaria crassna*); Kan pholiang kritsana nai saphap plot chua." Kasetsart University Annual Conference, Bangkok (Thailand), 30 Jan - 1 Feb 1995 publ. in *33. Kasetsart University annual conference, Kasetsart*

Univ., Bangkok (Thailand).- Bangkok (Thailand), 1995 pp 97-102. Abstract. Shoot tips and lateral buds of Agarwood Trees (*Aquilaria crassna*) were used as explants to determine effects of various cytokinins (BA, 2iP, kinetin) on modified MS medium and Woody Plant Medium (WPM). The results, BA was more effective in promoting multiple shoot than did 2iP or kinetin. Multiple shoots were produced from shoot tips and lateral buds of Agarwood cultured on both media supplemented with BA 0.25, 0.5, 1, 2 and 4 mg/l. Rooting of shoots in vitro were obtained on WPM containing IBA or without auxins. The survival rate of plantlets were 90 percent after transplanting in nursery.

Tran, Q.L., Tran, Q.K., Kouda, K., Nguyen, N.T., Maruyama, Y., Saiki, I., Kadota, S., 2003. "A Survey on Agarwood in Viet Nam.". *Journal of Traditional Medicines* **20**(3), 2003. pub. Medical and Pharmaceutical Society Wakan-yaku.

Uddin M.S., Mukul S.A., Khan M.A.S.A., Alamgir M., Harun Md. Y & Alam M.S. (2008) "Small-scale Agar (*Aquilaria agallocha* Roxb.) Based Cottage Enterprises in Maulvibazar District of Bangladesh: Production, Marketing and Potential Contribution to Rural Development." *Small Scale Forestry* **7**(2), 139-149. Abstract. Globally, trade in agar-based products is growing rapidly due to their recent adoption as an ingredient in the cosmetics and pharmaceuticals sector. In Bangladesh, people living in some north-eastern districts have been engaged in the production, processing and trading of such products for several decades. These practices, which they consider as the lifeblood of their existence, have been inherited from their ancestors. This paper reports a case study carried out in Maulvibazar district exploring the production and marketing, and industry problems, of agar-based enterprises and their potential contribution to socio-economic development. An exploratory survey was undertaken over 30 randomly selected agar-based factories during December 2005–April 2006, with entrepreneurs of the factories personally interviewed using a semi-structured questionnaire. The majority of the factories of the area were found to depend on local sources of raw materials to produce agar-based products. About 514 full and part-time workers are employed in the factories. Average annual expenditure, revenue and net annual income per factory for three consecutive years 2003–2005 of the study were estimated as Tk 63,980, Tk 111,414 and Tk 47,435, respectively, being highest where attar (agar oil) of superior grade was produced for export. There appears to be a sustainable source of raw materials, availability of technical and financial assistance and opportunity for expansion of market facilities to secure the maximum benefit achievable from this highly promising industry.

Watanabe H. (2003). "A trial on the practical production of aloewood in Lombok, Indonesia." *Tropical Forestry* **58,** 2–7. Abstract. Aloewood (agarwood or gaharu) is a resinous wood obtained from various species (mainly *Aquilaria* and *Gyrinops* spp.), which is used for perfumery, medicine and incense. This paper discusses aloewood production from *Gyrinops versteegii* in Indonesia.

Young C.M. (2001) "The extraction of the non-forest timber product mai hom (*Aquilaria crassna*) in Northeast Thailand" *Tropical Resources Institute Newsletter*, Spring 2001.

Zhang L., Brockelman W.Y. & Allen M.A. (2008) "Matrix analysis to evaluate sustainability: The tropical tree *Aquilaria crassna*, a heavily poached source of agarwood." Abstract. We used size-structured Lefkovitch projection matrix analysis to predict future trends in the survival of *Aquilaria crassna* (Thymelaeaceae), a tropical evergreen forest tree that has been highly sought after for its valuable aromatic wood (agarwood) for millennia. Data on growth, damage to trees by poachers, fruit production, seed dispersal and seedling recruitment were collected from a 30-ha plot in Khao Yai National Park, central Thailand that had seen moderate poaching. The population asymptotic growth rate, λa, and transient growth rate, λtr, found from using the matrix to project the observed population 48 years, were 1.002 and 1.005, respectively, with 95% confidence intervals of [0.985, 1.016] and [0.985, 1.023]. The stable size distribution obtained from the matrix was reasonably similar to the observed size distribution, suggesting that at the time of the study the population was not far from equilibrium. Sensitivity analysis and simulations of poaching on adult trees indicate that both λ's are very sensitive to the removal of adult trees and the growth of preadult trees. In particular, the increase in tree mortality and decrease in

preadult growth rate caused by agarwood collection seen in some areas could cause extirpation of the population. While in such cases the population appears to be poised on the brink of decline, several factors that we could not evaluate could alter its fate. First, adult deaths could stimulate recruitment of young under the parent trees; second, there is marked year-to-year variation in fruiting success and possibly recruitment; third, there is considerable spatial variation in tree density and recruitment, suggesting that attempts to evaluate future success need to encompass larger spatial and time scales.

Agarwood Toxicology

Howie AD, Boyd G. & Moran F. (1976) "Pulmonary hypersensitivity to Ramin (Gonystylus bancanus)." *Thorax* **31**, 585-587. Abstract. Transient airways obstruction associated with reduction in the transfer factor (diffusing capacity) of the lungs is reported in a patient with a clinical syndrome in keeping with extrinsic allergic alveolitis after exposure to Ramin dust (Gonystylus bancanus). The alterations in pulmonary function were consistently demonstrated on testing the patient in his working environment and were reproduced in the laboratory after inhalational challenge. The importance of the temporal relationship of changes in pulmonary function to contact with suspected allergenic material is emphasized.

Kim Y. C., Lee E. H., Lee Y. M., Kim H. K., Song B. K., Lee E. J. & Kim, H. M. (1997) "Effect of the aqueous extract of *Aquilaria agallocha* stems on the immediate hypersensitivity reactions." *Journal of Ethnopharmacology* **58**(1), 31-38. Abstract: We investigated the effects of the aqueous extract of *Aquilaria agallocha* Roxb. (Thymelaeaceae) on the immediate hypersensitivity reactions. The aqueous extract of *Aquilaria agallocha* stems showed inhibitory effects on passive cutaneous anaphylaxis, anaphylaxis induced by compound 48/80, and histamine release from rat peritoneal mast cells (RPMC). The morphological examination also clearly showed that the extract prevented the degranulation of RPMC in rats. The level of compound 48/80-induced intracellular cAMP in RPMC, when the extract was added, significantly increased about 8-fold at 10 s compared with that of basal cells. These results suggest that the aqueous extract of *Aquilaria agallocha* stems inhibits the immediate hypersensitivity reaction by inhibition of histamine release from mast cells.

Agarwood Status, Sustainability & Conservation

CIMAP (1997) *Indian Medicinal Plants Facing Genetic Erosion* p46-7.

Le Cong Kiet (2003). “History and Ecology of Agarwood in Viet Nam.” *Presentation given at Wood of the Gods: The First International Agarwood Conference, Ho Chi Minh City, Viet Nam*.

Gunn B.V., Stevens P., Singadan M., Sunari L. & Chatterton P. (2004) "Eaglewood in Papua New Guinea." *Resource Management in Asia-Pacific Working Paper No. 51*. pub. Resource Management in Asia-Pacific Program Research School of Pacific and Asian Studies, The Australian National University. Abstract. Papua New Guinea is arguably one of the last frontiers in the world where the exploitation of natural stands of eaglewood is possible. The trade in eaglewood first commenced in the late 1990s. Prior to the demand for export of eaglewood, the tree species had not been regarded as having any cultural or commercial importance. To date, only one species of eaglewood, Gyrinops ledermannii, is known to occur in Papua New Guinea. The lack of information and awareness of eaglewood is creating major problems exacerbated by the remoteness of producers and landowners who harvest the resin wood. There is an urgent need to develop a practical plan for scientifically-based biological conservation and management of eaglewood. This paper provides a general overview of eaglewood with specific reference to Papua New Guinea. Summary information on the recommendation contained in the strategy document on biological conservation and management of eaglewood is also presented.

Heuveling van Beek H., Phillips D. (1999) “Agarwood: Trade and CITES implementation in Southeast Asia. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.

Hoang T.C., Nguven D.T.L., "The conservation and use of *Aquilaria crassna* in Vietnam: a case study" Koskela J. (ed.), Appanah S. (ed.), Pedersen A.P.(ed.) Markopoulos MD *in Proceedings of the SE Asian moving workshop on conservation, Management & Utilisation of Forest Resources, Thailand 25 Feb - 10 Mar 2001.* FORSPA Publicn. 2002 No. 31, 155-157.

Kadir A.A., Ng L.K. & Ali A.R.M. (1997) "Economic aspects of *Aquilaria malaccensis* and its conservation in Malaysia". In: Productive Functions of Forests. *Proceedings of the XI World Forestry Congress* 13-22 Oct. 1997. Antalya, Turkey.

Newton A.C. & Soeharto T. (2001) "CITES and the conservation of tree species: The case of *Aquilaria* in Indonesia" *International Forestry Review* **3**(1), 27-33.

Soehartono T. & Newton A.C. (2000) "Conservation & sustainable use of tropical trees in the genus *Aquilaria*. I. Status and use in Indonesia." *Biological Conservation* **96** (2000), 83-94. Abstract. Tropical trees in the genus *Aquilaria* Lam. are the principal source of gaharu, one of the most valuable forest products traded internationally. Although these species are the focus of increasing conservation concern, information on their status and distribution is lacking. Information from herbarium accessions, a national forest inventory (NFI), field surveys and gaharu traders was used to assess the distribution of *Aquilaria* species in Indonesia, indicating population concentrations in Sumatra and eastern Kalimantan. Analysis of NFI data indicated that population densities are relatively low, with values generally <1.2 individuals ha−1; mean values recorded in field surveys were <0.6 individuals ha−1. Analysis of probability distributions emphasized the rarity of *Aquilaria* species, with a probability of encountering one or more individuals of *Aquilaria* in 1 ha being less than 0.2 in field assessments. Calculation of Morisita's index of dispersion indicated that the species are generally clumped, with Ip typically <0.6. Analysis of stand structure suggested continuous recruitment in some areas, but a general absence of larger individuals. Given current deforestation rates, these data suggest that all *Aquilaria* species in Indonesia classify as Vulnerable according to the IUCN Red List criteria.

Soehartono T. & Newton A.C. (2001) "Conservation & sustainable use of tropical trees in the genus *Aquilaria*. II The impact of gaharu harvesting in Indonesia." *Biological Conservation* **97**(1) 29-41. Abstract. *Aquilaria* spp. are the main source of gaharu, one of the most valuable non-timber products harvested from tropical forests. In order to assess the impact of gaharu harvesting on populations of *Aquilaria* spp. in Indonesia, the activities of gaharu collectors were assessed by accompanying them on collecting expeditions. Gaharu harvesting generally involved felling the tree, with 31–92% of trees encountered being felled. The quantity of gaharu obtained from each felling was extremely low, mean values ranging from 0.10–0.18 kg tree −1 to 0.19–2.13 kg tree−1 for high and low grade gaharu respectively. A combination of these values with gaharu trade figures for the early 1990s enabled the number of *Aquilaria* spp. trees harvested annually in Indonesia to be estimated. Values ranged from less than 30,000 to more than 100,000 trees felled, depending on the year. Field assessments of two populations of *Aquilaria* spp. were used to parameterize a matrix model, which was used to predict the impact of different harvesting regimes on population dynamics of the species. Values of the dominant latent root (λ) were 1.22 and 1.20 for *A. malaccensis* in West Kalimantan and *A microcarpa* in East Kalimantan respectively, indicating that both populations are self-sustaining in the absence of harvesting. Analysis of λ under different harvesting scenarios indicated that for *A. malaccensis*, population expansion will continue if harvesting is set at a minimum diameter at breast height (dbh) of above 10 cm, but for *A. microcarpa*, a population decline will occur if trees with a dbh of less than 30 cm are harvested. Given current harvesting practices, it is, therefore, unlikely that gaharu is being sustainably harvested at present. These results suggest that the gaharu trade may have had a substantial impact on the population size of *Aquilaria* spp. in Indonesia, and their implications are discussed in the context of setting harvest quotas for regulation of trade, as required by CITES.

Soehartono T. & Newton A.C. (2001) "CITES and the conservation of tree species: the case of *Aquilaria* in Indonesia" *Internat Forestry Review* **3**(1), 27-33. Commonwealth Forestry Assocn.

Soehartono, T. Newton & A. C (2002) “The Gaharu Trade in Indonesia: Is it Sustainable?” *Economic Botany* 56(3) pp271-284. Abstract. When subjected to a fungal attack, *Aquilaria* spp. (Thymelaeaceae) produce a fragrant resin that is traded internationally as gaharu. Socioeconomic aspects of the gaharu trade were investigated via interviews with collectors and local and international traders. In addition, the extent of local and international trade was evaluated by reference to official government statistics. Evidence that gaharu resources are declining was obtained from the personal experience of gaharu collectors, and official statistics relating to the declining number of gaharu export companies in operation. Traders also reported that the main source of gaharu has recently switched from Sumatra and Kalimantan to sources in eastern Indonesia (Maluku and Irian Jaya), a finding supported by official statistics. Disparities recorded between official figures for the price and volume of gaharu in local and international trade, supported by comments made by export traders, indicate that a high proportion of the more valuable, high-grade gaharu is traded illegally by personal transaction. Interviews with gaharu collectors indicated that traditional approaches to harvesting are declining, as more nonlocal people become involved in collection, leading to more intensive harvesting practices. Together, these findings suggest that the current Indonesian trade in gaharu is not sustainable.

Takeuchi W, Golman M. (2002). “The identity of eaglewood (*Gyrinops*, Thymelaeaceae), a new economic resource for Papua New Guinea. *Sida, Contrib. Bot*. **20**.(1): 261-267.

White E., Hunter J., Dubetz C., Brost R., Bratton A., Edes S. & Sahota R. (2000) “Conservation and sustainable use of tropical trees in the genus *Aquilaria* II. The impact of gaharu harvesting in Indonesia. *J. Chem. Technol Biotechnol*. **75**, 923–926.

Yip, J.K.L & Lai, PCC (2003) “The nationally rare and endangered plant, *Aquilaria sinensis*: its status in Hong Kong” – see
http://www.hkherbarium.net/Herbarium/topics/Aquilaria/Aquilaria_E.htm

Zich F. & Compton J. (undated) “The final frontier towards sustainable management of Papua New Guinea’s agarwood resources." A TRAFFIC Oceana report in conjunction with WWF.

Agarwood Uses, Applications & Trade.

De Agar M. (CITES Nov 2003) “Review of significant trade *Aquilaria malaccensis*.” CITES PC14. Doc 9.2.2. Annex 2.

Anon. (2004) “Review of Significant Trade *Aquilaria malaccensis” CITES PC14 Doc.9.2.2 Annex 2*

Barden A., Awang A., Mulliken T. & Song M. (2000) “Heart of the matter. Agarwood use and trade and CITES implementation for *A. malaccensis*..” TRAFFIC International, Cambridge, UK.

Burfield T. (1994) “Agarwood Oil.” Presentation to the British Society of Perfumery, Hilton Hotel, Milton Keynes, UK 1994 (as reported in *SPC* June 1994 p63).

Burfield T... "Oud (aka Aloeswood or Agarwood Oil) *Scensitivity* ??

Burkhill I.H. (1935) *Dictionary of economic products of the Malay Peninsula* Vols 1-2 Crown Agents for the Colonies, London, Vol 1 A-H.

Chakrabarty K., Kuner A., & Manon V. (1994) “Trade in Agarwood" *WWF-India* Traffic India, New Delhi.

Clear A. (2000) "Gaharu mania sweeps across Irian-Java." *Crazy-Man Documentaries* - see http://www.kabar-irian.com/int-feb00.htm. .

Clifford T. (1984) *Tibetan Buddhist Medicine & Psychiatry:* The Diamond Healing Motilal Barnarsidas Publishers Pvt Ltd Delhi p207-8.

Compton J. & Ishihara A. (undated) "Use and Trade of Agarwood in Japan." Report compiled by James Compton, TRAFFIC Southeast Asia and Akiko Ishihara, TRAFFIC East Asia-Japan For the CITES Secretariat Report.

DeBeer, J. H. (1993). "*Rattan for rice, eaglewood for salt. Some notes on Punan resource utilization in Bulungan, East Kalimantan."* Unpublished manuscript.

Guha S.R.D. & Karita B.C. (1976) "Chemical pulps for writing & printing papers from *Aquilaria agallocha* Roxb. (Agarwood)." *Indian Pulp & Paper* **30**(6) 16-17.

Gianno R. (1986) "The exploitation of resinous products in a lowland Malayan forest" *Wallaceana* **43**, 3-6.

Gianno R. (1990) *Semelai culture and Resin Technololgy*. Conneticut Academy of Arts & Sciences, New Haven.

Dass D.K. (1963) "The Agar industry in Pakistan" *Pakistan Journal of Forestry* **13**(2), 194-197.

Domke, W. (1932) Zur Kenntnis einiger Thymelaeraceen. Notizblatt des Botanischen Gartens und Museums zu Berlin - *Dahlem* **11**, 348-363.

Donovan D.G. & Puri R.K. (2004) "Learning from traditional knowledge of non-timber forest products: Penan Benalui and the autecology of *Aquilaria* in Indonesian Borneo". *Ecology and Society* **9**(3), 3. Abstract. Traditional knowledge, promoted to make conservation and development more relevant and socially acceptable, is shown to have an important role in identifying critical research needs in tropical ecology. Botanists, foresters, and phytochemists, among others, from many countries have sought for decades to understand the process of resin formation in the genus *Aquilaria*, a tropical forest tree of South and Southeast Asia. Not every tree develops the resin and, despite extensive scientific research, this process remains poorly understood. Attempts at cultivating the valuable aromatic resin, gaharu, have been uneven at best. Thus, gaharu remains largely a natural forest product, increasingly under threat as the trees are overexploited and forest is cleared. In this paper, we compare scientific knowledge and traditional knowledge of the Penan Benalui and other forest product collectors of Indonesian Borneo. Although limited management of wildlings failed to bring the resin-producing species under cultivation, we found that the Penan recognize the complex ecology of resin formation involving two, or maybe three, living organisms-the tree, one or more fungi, and possibly an insect intermediary. Developing a sustainable production system for this resource will require a clear understanding of how these various natural elements function, separately and synergistically. Traditional knowledge can help fill gaps in our information base and identify promising areas for future research. Both correspondence and gaps in knowledge support the call for a greater role for ethnobiological research and interdisciplinary cooperation, especially between ethnobiologists and foresters, in developing sustainable management systems for this traditional resource and its natural habitat.

Edwards, Victoria (1996) "The Oil of Ud" *Aromatherapy Quarterly* Vol **50** Autumn 1996

Franchomme P. & Peneol D. (1990) *l'Aromathérapie excactment* pub. Jollois.

Foucaud A, Reveillere H, & Mahe M. (1968) "Aloes-wood, agalloch-wood, eagle-wood" *Presse Med.* 1968 **76**(21), 1028-9.

Gatten, A. (1977) "A Wisp of Smoke" *Monumenta Nipponica* **32**, 35-48.

Gutha S.R.D. & Karira B.G. (1976) "Chemical Pulps for writing and printing papers from *Aquillaria agallocha*" *Indian Pulp Paper* **30**(6) 16-17 (April/May 1976).

Hansen E. (2000) "The hidden history of a scented wood." *Saudi Aramco World* XX, 2-13.

Harris T. (2004) "Agarwood Gem of Truth" *Aromatherapy Journal* Summer/Autumn 2004

Hartadi, I. (1997) "The hunt for gaharu. Gaharu, a rare commodity already on Appendix II of CITES is still collected in large quantity" *Conservation in Indonesia* **13**(2) Industri Hidupan Liar (The Wildlife Industry) WWF Jakarta.

Hearn L. (1971) *In Ghostly Japan* Rutland Vt., Tuttle, 1971. - now as paperback (2004): Capricorn Publishing 2004 ISBN: 0975397028.

Hidayat, R. (1996). Gaharu and Kampung Pengembara. Pancaroba. Musim.

Hooper D. (1904) *The Agri Ledger* No 1.

Hsu H-Y. (1996) *Oriental Materica Medica* rev edn 1996. p403.

Yaacob, S. (1999). Agarwood*: Trade and CITES Implementation in Malaysia*. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.

Jantan, I. (1990). "Gaharu." *Timber Digest* **107**: December. 1990.

Kalita, J., Bhattacharyya P. R. & Nath S. C. (2002) "*Heortia vitessoides* Moore (Lepidoptera: Pyralidae) - A serious pest of Agarwood plant (*Aquilaria malaccensis* Lamk.)" *Geobios-Jodhphur* **29**(1), 13-16. Abstract. The field and laboratory investigations were carried out on the biology of Heortia vitessoides in the Agarwood plantations during 1998. The pest being active from March to mid-November, has seven to eight overlapping generations in year. There are five larval instars and total larval duration was 23.50′0.49 days. Pupation takes place below soil surface and pupal duration was 8.17′0.64 days. The adult lives for 4.17′0.51 days. The female lays eggs in masses of 350-550 under surface of the leaf after one to two days of mating. The incubation period is 10.50′0.75 days and the life cycle is completed in 46.34′0.45 days. In severe infestation, the pest completely denuded the leaves.

Koopman & Diemont (2004-3) “North-South Policy Brief” for Programme International Cooperation. Online URL: www.north-south.nl

Krishnan S. (1997) "A whiff of the past" *Indian Express Newspapers Bombay.*

Iu, K.C. (1983) “The cultivation of the "Incense Tree" (*Aquilaria sinensis*)" *J of the Hong Kong Branch of the Royal Asiatic Society* **23**, 247-249

LaFrankie J.V. (1994) "Population dynamics of some tropical trees that yield non-timber forest products" *Economic Botany* **48**(3), 301-309.

Le Cong, K. (1996). The history of Agarwood in Viet Nam. *Paper Presented at the International Conference of the Society of Ethnobiology, Nairobi, Kenya*.

Le Nho (2002) "Wood of the Gods" *Vietnam Investment Review* November 2002.

Li, Shizen (1596) *Pan Ts'ao Kang Mu* **34**.

Lok E.H. & Yahyda A.Z. (1996) "The growth and performance of plantation grown *Aquilaria malaccensis* in Peninsula Malaya." *J. Trop For. Sci* **8**, 573-575

Lok EH, Chang Y, Aziah MY (1999) "Early survival & growth in field trials of *Aquilaria malaccensis* (karas) and *Azadirachta excelsa* (sentang)." J*. Trop Forest Sci* **11**(4), 852-854.

Mai, R.R. & Suripatty, B.A. 1996. Pengaruh Wadah Penyimpanan dan Kelas Diamter Terhadap Pertumbuhan Stump Wikstroemia polyantha. *Buletin Penelitian Kehutanan*, Volume **1**. No. 1 (1996). Balai Penelitian Kehutanan, Manokwari, Irian Jaya.

Mandang Y.I. & Wiyono B. "Anatomy of eaglewood (*Aquilaria malaccensis* Lam.) and several related species" The Fifth Pacific Regional Wood Anatomy Conference. *Abstracts from the Meeting of the IAWA Pacific Regional Group & IUFO S 5.01 (Wood Quality), Jakarta Indonesia 9-14 Sept. 2002. IAWA Journal* 2002 **23**(4), 471.

Maruyama Y., Saiki I. & Kadota S. (2003). "A survey on agarwood in Vietnam." *Journal of Traditional Medicine* **20**(3), 124-131.

Miller L. & Miller B. (1995) *Ayerveda & Aromatherapy* Lotus Press Twin Lakes WI USA.

Mohd P.M., Fui L., Fui L.H., (2002) "Importance of Gaharu harvesting to the household economy" In Chang Y. (ed.), Mohtar M. (ed.) Subramaniam V. (ed.) Yunos N.M. *Towards Modernisation of Research & Technology in Herbal Industries - Proceedings of the Seminar on Medicinal & Aromatic Plants 24-25 July 2001 2002* 204-209 publ. FRIM Kuala Lumpur, Malaysia.

Momberg F., Jessup T., & Puri R. (1997) "Gaharu collecting in the Kayan Mentarang Nature Reserve; problems and prospects for sustainable community-based forest management in East Kalimantan" *Indonesia WWF Publications,* Jakarta.

Momberg F., Puri R.K. & Jessup T. (2000) “Exploitation of gaharu, and forest conservation efforts in the Kayan Mentarang National Park, East Kalimantan, Indonesia.” pp 259–284 *in* C. Zerner, editor. *People, plants, and justice: the politics of nature conservation.* Columbia University Press, New York, New York, USA.

Moore M. & Rompies K. "The Money Tree" *The Sydney Morning Herald* Jan 5th 2005.

Morita K. (1992) *The Book of Incense* Kodansha International

Oyen LPA & Nguyen XD (1999) (eds.) *Plant resources of SE Asia 19: Essential oil plants* eds Backhuys Pubs Leiden 1999. PROSEA Bogor Sept (2003).

Paoli G. D., Leighton M., Peart D.R. & Samsoedin I. (1994) "Economic ecology of gaharu (*Aquilaria malaccensis*) in Gunung Palung National Park: valuation of extraction and ecology of the residual population." Unpublished manuscript.

Paoli G. D., Peart D. R., Leighton M. & Samsoedin I. (2001) "An ecological and economic assessment of the non-timber forest product gaharu wood in Gunung Palung National Park, West Kalimantan, Indonesia". *Conservation Biology* **15**(6),1721-1732.

Parry E.J. (1925) *Parry's Cyclopaedia of Perfumery: A Handbook* Vol 1 A-L. pub J & A. Churchill London.

Pereira, I. (1995). “Notes On: Pepper (*Piper nigrum*), Mai Kessina (The Eagle Wood Tree), and Cardamom (*Elettaria cardamum*),. “ NDCP\DDSMS\LAO\89\550, Lao PDR.

Priyadi, Y. (1999). *Agarwood: Trade and CITES Implementation in Indonesia*. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.

Puzari K.C. & Saikia U.N. (2001) "Investigation on the formation & development of agaru in *Aquilaria agallocha* Roxb. Proceedings of *Seminar on Scope & Dimension of Agar Plantation in NE region*. Edits M. Ahmed, P. Gogol & G.U. Ahmed pp 61-69, AATMA, Hojai, India.

Revolutionary Health Committee of Hunan Province (1978) *A Barefoot Doctors Manua*l rev. & enlarged edn. pub. Routledge & Kegan Paul, London 1978.

Shaw K. (1966) "Development issues: tropical forests and aromatic plants as non-timber forest products" from *Lecture Notes 2.8.1996 at Purdue Univ, Indiana, Training Program on Essential Oils.*

Shyun C. Y. (1997) "Gaharu. "FRIM In Focus" *The Forest Research Institute Malaysia*, Jan 1997.

Sidiyasa K. *et al.* (1986) ["Exploration and study of regeneration of 'gaharu' producing substances in Kintal forest region, South Kalimantan"]. *Bulletin Penelitian Hutan* **474**, 59-66.

Singadan M., Yelu W., Beko J., Bosimbi D. & Boland, D.J. (2001). "Some aspects of the eaglewood trade in Papua New Guinea. FAO Forest Genetic Resources" in *Non-Wood News* No **9**, pp 49-51.

Singadan M., Sunari L., & Fazang K. (2002). "Gaharu trade on the Keram River area of Madang Province, Papua New Guinea. Part of the 'Domestication of Papua New Guinea's Indigenous Forest Species" Project managed by CSIRO, Forestry and Forest Products, Canberra, Australia in conjunction with WWF South Pacific Programme, Madang, PNG and PNG Forest Research Institute, Lae, PNG.

Singadan, M. (2003). "Personal perspective of the eaglewood trade in Papua New Guinea.". Paper presented to the 'First International Agarwood Conference', Ho Chi Minh City, Viet Nam, 10-15 November, 2003.

Soehartono T., Newton & A. C. Mardiastuti A. (2002) "Factors influencing the survival and growth of *Aquilaria malaccensis* seedlings in Indonesia" *Journal of Tropical Forest Science* **14**(3), 364-378 Forest Research Institute Malaysia.

Soehartono T. (2003) "Sustainable trade in agarwood and ramin in Indonesia" Paper presented at the *Workshop on National Strategy and Trade of Trees in Indonesia. Indonesian Institute of Sciences – Centre for Biological Research. Bogor Sept 2003.*

Subeham, Junya U., Fujino H., Attamimi F., Kadota S (2005) "A field survey of agarwood in Indonesia" *J of Trad. Medicines* **22**(4), 244-251. Abstract: Agarwood is one of the most valuable non-timber forest products harvested from the tropical forests in S.E. Asia. We have surveyed agarwood in Indonesia which is performed through interviewed collectors, businessmen, and government officers (Ministry of Forestry, East Kalimentan, Indonesia) and also surveyed the wild agarwood and its cultivation in South Sulawesi & East Kalimantan Provinces. High economic value is one of the reasons for collecting agarwood to increase family income of the peoples living by the forest. Each surveyed area has a different classification and price of each grade, according to their experience by observing the darkness, smell, oily and density of agarwood. Over exploitation of the natural resource makes the stock becoming exhausted. It has been an initiative for the conserving the plant of source agarwood by cultivation. Fungi, the known stimulators in formation of agarwood, are used in the cultivation of agarwood. *Fusarium laseritum* is the faster fungus infecting *Aquilaria* sp. tree, and can be isolated and inoculated easily into medium. Thus, this fungus is inoculated into holes in the trunk. One year after inoculation obtained agarwood with the lowest grade. This cultivation program was supported by the Indonesian government through research & training to the collector who cultivate agarwood.

Sunari, L. B. & Singadan, M. (2002). *Report of a survey trip to examine gaharu trade in the Yapsiei area, Sandaun Province, Papua New Guinea. 11-22 March 2002. Internal report by WWF South Pacific Programme, Madang PNG in conjunction with PNG Forest Research Institute, Lae, PNG.*

Yoneda K., (1999). *On the trip on expeditions on traditional medicines and fragrances in Laos (1) – Research on the materials of fragrances.* Koryo No. 203.

Yoneda K. (1999). "*On the trip on Expeditions on traditional medicines and fragrances in Laos (2) – Collect and Researches on Agarwood.". Koryo* No. **204**, 33-38. .Abstract. The opium which produced in mountain area of northern Laos is a famous products in Cochinechina. Mountain peoples are restricted the usage of opium in their daily life. The collecting way of agarwood was found out in native woodlands in Laos. The causes of productions of resin and flavour of agarwood are not cleared. One of cause is the protection from injuries with ants. (author abst.)

Yoneda K. (2000). "*On the trip on Expeditions on traditional medicines and fragrances in Laos (3) – On the Resources of Agarwood.".* Koryo No. **205**, 33-38. Abstract. The conservation of *Aquilaria* spp. were important epoch in WWW traffic ASIA. So, I have done research on the resources of *Aquilaria* spp. in LAOS.P.D.R. We can find out of live agarwoods easily from all over the nation land. After this research we had found 3 or more *Aquilaria* species which are distributed in LAOS. After this, the afraid of emergency of extinction of *Aquilaria* spp. are not exist in LAOS, from this time to near future. (author abst.).

Agarwood – Pharmacological Effects.

Hara H, Ise Y, Morimoto N, Shimazawa M, Ichihashi K, Ohyama M & Iinuma M. (2008) "Laxative effect of agarwood leaves and its mechanism." *Biosci Biotechnol Biochem*. **72**(2), 335-45. Abstract. We investigated the laxative activity of an extract of agarwood leaves from *Aquilaria sinensis*. The laxative activity was measured in mice by counting the stool frequency and stool weight, and the drugs were orally administered. An acetone extract of agarwood leaves and senna (a representative laxative drug) both increased the stool frequency and weight, but a methanol extract did not. The laxative effect of the acetone extract was milder than that of the anthraquinoid laxative, senna, and the former did not induce diarrhea as a severe side effect. We identified the main constituent contributing to the laxative effect of the acetone extract as genkwanin 5-O-beta-primeveroside (compound 4). Compound 4 strengthened the spontaneous motility and induced contraction in the ileum. This ileal contraction induced by compound 4 was inhibited by atropine, but not by azasetron, suggesting that the effect of compound 4 was mediated by acetylcholine receptors, and not by serotonin. The laxative mechanism for compound 4 may in part involve stimulation of intestinal motility via acetylcholine receptors.

Huong D.T.L, Dat N.T. Van Minh C, Kang J.S., & Kim Y.H. (2002) "Monoxidase Inhibitors from *Aquilaria agallocha*" *Natural Product Sciences* **8**,30-33 Korean Society of Pharamocognosy 1226-3907.

??(1997) "Antiallergic effect of Aquilarium lignum" *Yakhak Hoeji* **41**(2), 255-259.

Miniyar P.B., Chitre T.S., Deuskar H.J., Karve S.S. & Jain K.S. (2008). "Antioxidant activity of ethyl acetate extract of *Aquilaria agallocha* on nitrite-induced methaemoglobin formation." *Int J Green Pharm* **2**, 116-7 Abstract. *Aquilaria agallocha* Roxb, family, Thymelaeaceae, is an evergreen plant of India, China and Tibet, commonly described as aloe wood or agarwood. Traditionally, the bark, root and heartwood are used for their medicinal properties as a folk medicine to treat inflammation, arthritis, vomiting, cardiac disorders, cough, asthma, leprosy, anorexia, headache and gout. The present study was carried out to investigate the antioxidant activity of ethyl acetate extract of *Aquilaria agallocha* (EAA). EAA was tested in vitro at different concentrations for inhibitory effect on nitrite-induced oxidation of haemoglobin in human blood haemolysate. Results indicate a strong antioxidant effect of EAA in a concentration range of 500-

3500 µg/ml. However pro-oxidant activity was observed at higher concentrations of these compounds.

Okugawa H., Uneda R., Matsumoto K., Kawanishi K. & Kato K. (2000) "Effects of sesquiterpenoids from Oriental incenses on acetic-acid induced writhing and D2 and 5-HT2A receptors in Rat Brain" *Phytomedicine* **7**(5), 417-422.

Okugawa H., Ueda R., Matsumoto K., Kawanishi, K. & Kato, A. (1996) "Effect of jinkoh-eremol and agarospirol from agarwood on the Central Nervous System in mice" *Planta Medica* **62**(1), 2-6. Abstract: Agarwood (Jinkoh in Japanese) one of the Oriental medicines, is used as a sedative. The benzene extract of this medicine showed a prolonged effect on hexobarbital-induced sleeping time, and hypothermic effects in terms of rectal temperature, a suppressive effect on acetic acid writhing, and a reduction in spontaneous motility in mice. By repeated fractionation, oral administration in mice, and pharmacological screening, the active principles, jinkoh-eremol and agarospirol, were obtained from the benzene extract. They also gave positive effects on the central nervous system by peritoneal and intracerebroventricular administration. They decreased both methamphetamine- and apomorphine-induced spontaneous motility. The level of homovanillic acid in the brain was increased by them, while the levels of monoaminesand other metabolites were unchanged. Similar results wete seen in chlorpromazine-administered mice. Therefore, jinko-eremol and agarospirol can be considered to be neuroleptic.

Okugawa H., Ueda R., Matsumoto K., Kawanishi K. & Kato, A. (1993) "Effect of agarwood on the Central Nervous System in mice" *Planta Medica* **59**(1), 32-6. Abstract: Agarwood (Jinkoh in Japanese) is an Oriental medicine for use as a sedative. Neuropharmaclolgical studies have been conducted with the extracts of petroleum ether, benzene, chloroform, and water from agarwood (*Aquilaria* sp. probably *A. malaccensis* Benth.) in mice. The benzene extract showed a reducing effect in spontaneous motility, a prolonging effect on hexobarbiturate-induced sleeping time, a hypothermic effect in terms of rectal temperature, and a suppressive effect on acetic-acid writhing by oral administration. Fr. 1 of the three fractions which were obtained by benzene extract by column chromatography was found to produce more positive effects on these neuropharmalogical tests than the original benzene extract. These facts suggest that benzene extractable compounds of agarwood possess potent central nervous system depressant activities.

Okukawa H., Kawanishi K. & Kato A. (2000) "Effects of sequiterpenoids from Oriental incenses on sedative & analgesic action" *Aroma Research* **1**(1), 34-38.

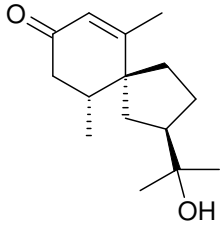
Suvitayavat W., Tunglert S., Thirawarapan S.S., Kitpati C. & Bunyapraphatsara N. (2005) “Actions of Ya-hom, a herbal drug combination, on isolated rat aortic ring and atrial contractions.” *Phytomedicine* **12**(8), 561-569. Abstract: The effect of the popular Thai medicine Ya-hom on cardiovascular function was studied in isolated rat aortic ring and atrium by comparison with norepinephrine (NE). Ya-hom contains extracts of *Agastache rugosa*, *Acorus gramineus*, *Lysimachia foenum-graecum*, *Citrus nobilis*, *Magnolia officinalis*, Cinnamomum cassia (C. aromaticum), *Asarum sieboldii*, *Ligusticum wallichii*, *Glycyrrhiza glabra*, *Eugenia caryophyllata* (*Syzygium aromaticum*), *Saussurea lappa*, *Aquillaria agallocha*, *Atractylis ovata* & *Angelica anomala*. Water extraction of ya-hom at 0.83, 1.67, 8.33, & 16.67mg/ml stimulated aortic ring contraction dose-dependently. The maximum concentration, at 16.67 mg/ml was ~14% that of NE. This stimulatory effect of Ya-hom was inhibited partially by phentolamine, which indicated that the effect of Ya-hom was partly dependent on the alpha receptor, similar to NE. Administration of Ya-hom with NR decreased the force of aortic ring contraction compared to the effect of NE alone, indicating the Ya-hom may have a partial alpha-agonist activity. Ya-hom at concentrations of 1.67, 8.33 & 16.67 mg/ml showed a dose-dependent positive inotropic and negative chronotropic effects. Ya-hom increased the force of isolated atrial contraction with slow onset and prolonged action. In contract to NE which acted on beta 1 reeceptor, causing positive inotrophic & negative chromotrophic effects, propanolol did not alter the effect of Ya-hom on the atrial contraction. This shows the action of Ya-hom on atrial contraction does not involve the beta-

receptor. This study demonstrated that the selected Ya-hom preparation increased vascular smooth muscle contraction, increase the force, but decreased the rate of atrial contraction.

Suvitayavat W., Tunglert S., Thirawarapan S.S., & Bunyapraphatsara N. (2005) “Effects of Ya-hom on blood pressure in rats.” *J. of Ethnopharmacology* **97**(3), 503-508. Abstract. The effects of Ya-hom a traditional Thai formulation, on blood pressure were evaluated to verify its use for fainting treatment. Ya-hom has several recipes which are composed of different herbal plants in varying ratio. We have selected the most popular commercial preparation to determine the effect on blood pressure in rats. The water extract of Ya-hom at doses of 0.2, 0.4, 0.6 and 0.8g/Kg initially transiently decreased pressure and over time, increased blood pressure. The duration of the Ya-hom effect of decreasing & increasing blood pressure was dose dependent. Phentolamine attenuated the blood pressure decreasing effect but did not affect the blood pressure increasing effect of Ya-hom. Ya-hom was previously shown to increase aortic ring contraction which was partially inhibited by phentolamine, and increased atrial contraction. It is possible that phentolamine inhibits the effect of Ya-hom on vascular smooth muscle contraction resulting in a prominent positive inotropic effect. This may be the same reason that phentolamine does influence the effect of Ya-hom on increasing the blood pressure. The dominant effect of Ya-hom on increasing the blood pressure supports the use of Ya-hom for the treatment of fainting.

Takemoto H., Ito M., Shiraki T., Yagura T. & Honda G. (2008) "Sedative effects of vapor inhalation of agarwood oil and spikenard extract and identification of their active components." *J Nat Med* **62**, 41–46. Abstract. Agarwood oil and spikenard extract were examined for their sedative activity using a spontaneous vapor administration system. It was shown that inhalation of agarwood oil vapor sedated mice. The main volatile constituents of the oil were found to be benzylacetone [agarwood oil from a Hong Kong market (1)], or a-gurjunene and (+)-calarene [agarwood oil made in Vietnam (2)]. A hexane extract of spikenard contained a lot of calarene, and its vapor inhalation had a sedative effect on mice. Individual principles benzylacetone, calarene, and agurjunene were administered to mice, which reproduced the result of the corresponding oil or extract. However, the most effective dose of the compounds was lower than their original content in the oil and extract (benzylacetone 0.1%, calarene 0.17%, a-gurjunene 1.5%).

Ueda J-Y.. Imamura L.,Tezuka Y., Tran Q.L.., Tsuda M. & Kadota S. (2006) "New sesquiterpene from Vietnamese agarwood and its induction effect on brain-derived neurotrophic factor mRNA expression in vitro." *Bioorganic & Medicinal Chemistry* **14**(10),3571-3574. Abstract. Agarwood, one of the valuable non-timber products in tropical forest, is a fragrant wood, whose ethereal fragrance has been prized in Asia for incense in ceremony, as well as sedatives in traditional medicine. We separated the 70% EtOH extract of Vietnamese agarwood, which showed significant induction effect on brain-derived neurotrophic factor (BDNF) mRNA expression in rat cultured neuronal cells, to isolate a new compound and a 2-(2-phenylethyl)chromone derivative. The new compound was determined to be a spirovetivane-type sesquiterpene, (4R,5R,7R)-1(10)-spirovetiven-11-ol-2-one, by spectroscopic data and showed induction effect of BDNF mRNA. Graphical Abstract. The new sesquiterpenoid (4R,5R,7R)-1(10)-spirovetiven-11-ol-2-one, isolated from agarwood significantly induced brain-derived neurotrophic factor (BDNF) exon III–V mRNA expression.



(4R,5R,7R)-1(10)-spirovetiven-11-ol-2-one

Yang J.S., Wang Y.L., Su Y.L., He D.H., Zheng Q.T. & Yang J (1989) "Studies on the chemical constituents of *Aquilaria sinensis* (Lour) Gilg. III. Elucidation of the structure of isobaimuxinol and

isolation and identification of the constituents of lower boiling fraction of the volatile oil," *Yao Xue Xue Bao* **24**(4):264–268.

Zhou Y.B. (1988) "[Pharmacological actions of lignum Aquilariae Resinatum (*Aquilaria agallocha* Roxb.) on the smooth muscle of intestines]" *Zhong Yao Tong Bao* **13**(6),40-2, 64.

Zhou M, Wang H, Suolangjiba , Kou J, Yu B. (2008) "Antinociceptive and anti-inflammatory activities of Aquilaria sinensis (Lour.) Gilg. Leaves extract." *J Ethnopharmacol.* **117**(2), 345-350. Abstract. AIM OF THE STUDY: The analgesic and anti-inflammatory activities of the ethanol extract of *Aquilaria sinensis* (Lour.) Gilg. Leaves were observed in various experimental models related to nociception and inflammation, so as to provide some evidence for its traditional use. MATERIALS AND METHODS: Acetic acid-induced writhing and a hot plate test in mice were used to evaluate its analgesic activity. On the other hand, its anti-inflammatory activity was observed in xylene or carrageenan-induced edema, carboxymethylcellulose sodium (CMC-Na)-induced leukocyte migration in mice and lipopolysaccharide (LPS)-induced nitric oxide (NO) release from mouse peritoneal macrophages in vitro. RESULTS: The ethanol extract significantly inhibited acetic acid-induced writhing after single oral administration at doses of 424 and 848mg extract/kg, and the response to the thermal stimulus in mice at the dose of 848mg/kg. Meanwhile, the ethanol extract also remarkably lessened xylene-induced ear swelling, carrageenan-induced paw edema, and CMC-Na-induced leukocyte migration. Furthermore, the extract considerably reduced NO release from LPS-stimulated macrophages with IC(50) of 80.4mg/ml. CONCLUSION: These findings suggest that *Aquilaria sinensis* (Lour.) Gilg. Leaves extract present notable analgesic and anti-inflammatory activities, which support its folkloric use for some diseases related with painful and inflammatory conditions such as trauma etc.

Agarwood- General & Uncategorised.

Mahindru S.N. (1992) *Indian Plant Perfumes* pub Metropolitan, New Delhi p103-104.

Chaudhari D.C. (1993) "Agarwood from *Aquilaria malaccensis* Lam. (*A. agallocha* Roxb.) *MFP News* **3**(4) pp 12-13.

Ito M. (2008) "Studies on perilla, agarwood, and cinnamon through a combination of fieldwork and laboratory work. *J Nat Med*. **62**(4):387-95. Abstract. Fieldwork is one of the primary methods for studying medicinal plants and materials, and information thus obtained can be valuable for experiments performed in the laboratory. Meanwhile, results of experiments in the laboratory can be brought back to the field for verification and further investigation. A combination of field and laboratory work has led to effective progress in studies of medicinal plants in the field of pharmacognosy. However, the collection of samples with information through fieldwork is not easy, and it fundamentally requires a great deal of research experience. Geographical, ethnical, and political affairs often affect its performance, and to establish a good cooperative relationship with foreign localities is inevitably required. Beyond these difficulties, fieldwork can provide a framework for the research project and excellent and unique viewpoints concerning the target. This review article describes studies on perilla, agarwood, and cinnamon, focusing mainly on the results of fieldwork performed in Indochina on these species. All three of these medicinal plants contain essential oils, and their composition varieties, biosynthetic pathways, pharmacological activities, or induction mechanisms for production are principally investigated through shuttling between fieldwork and laboratory experiments.

Persoon G.A. (2007) "Agarwood: the life of a wounded tree." *IIAS Newsletter* No. **45,** 24-5. Publ. IIAS, Leden, - see https://openaccess.leidenuniv.nl/dspace/bitstream/1887/12820/1/IIAS_NL45_2425.pdf

Punithalingam E. *et al.* (1978) "Phomopsis species from *Aquilaria agallocha*" *Nova Hedwigia* **29,** 251-255 (1978).

Pybus D. *Kodo - The Way of Incense*. Speaking Tree Books.

Tenzin K. & Gyeltshen N. (2004?) "Pilot Agar wood plantation in Zhemgang and Sarpang." - see http://www.moa.gov.bt/moa/rcjakar/orig/for/agur_prop.pdf

Universitas Nusa Cendana (1996). Prospek Pengusahaan Gaharu di Nusa Tenggara Timur: Studi

Wiriadinata H. (1995) “Gaharu, *Aquilaria* spp.” *Perkembangandan pemanfaatan berkelanjutan. Lokakarya pengusahaan hasil hutan non kayu Indonesia. Surabaya, 31 Juli-1 Agustus 1995*.

WWF, 1999. Eaglewood-background information. Unpublished paper prepared by the World Wide Fund for Nature.

Yamada I. (1995) “Aloeswood Forest and the maritime World”. *South East Asian Studies* **33**(3), 181-186.

Yamanaka, Akihiko (1981) “Jinko, the scented wood of *Aquilaria aquallocha* Roxb.” *Koryo* **134**, 61-4.

Yamada K. (1979) Koryo Hakubuttan Jiten [Encyclopaedia of Incense] Dohosba.