Agarwood manufacturing: a multidisciplinary opportunity for economy of Bangladesh - a review

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Abstract: A variety of methods, ranging from natural to artificial, which have been practiced for producing agarwood and the economic opportunity related with this field in Bangladesh were reviewed. The anatomy of agar tree was also described. Agarwood is the fragrant resin-infused wood derived from the wounded trees of Aquilaria species. It is a valuable non-timber forest product used in fragrances and medicine. Artificial agarwood inducing methods serve as a way to supply agarwood and conserve the wild Aquilaria stock. The existing artificial methods are Nailing, Drilling, Aeration, Agar-wit, Partly-Trunk-Pruning, Burning-Chisel-Drilling, Fungi-Inoculation, etc. The quality of agar mostly depends on the plant species and the fungal species, as well as certain other unknown factors. Agar is a new commercial tree in Bangladesh, necessary steps should be taken immediately to make it popular among farmers and small entrepreneurs. Substantial amount of foreign currency would be saved through manufacture and export of agarwood.

Keywords: Aquilaria, anatomy of Aquilaria, Agarwood induction, economy.

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1 Introduction

Agarwood is a dark resinous heartwood that forms in *Aquilaria* and *Gyrinops* trees in the plant family Thymelaeaceae (Blanchette, 2006). It is highly prized that is extremely rare. It has at least a 3000 years history in the Middle East, India, China and Japan (Le, 2003). In Japan, agar incense is more expensive than gold (Japan Talk, August 26, 2012). The value of agarwood shipped out of Singapore alone each year has been estimated to exceed $ 1.2 billion (Hansen, 2000). This aromatic resinous wood has many common names including agarwood, gaharu, eaglewood, aloeswood, agila wood, aguru, agar, oud, ude, ud, ood, oode, jinkoh, jinko, Ch'Ing Kuei Hsiang, Ch'En Hsiang, Chan Hsiang, Chi Ku Hsiang, Huang Shu Hsiang, kalambak, grindsanah, etc (Blanchette and Van Beek, 2005). Agarwood is a diseased tissue corresponding production of oleoresin which begins to become odoriferous and this aromatic resinous wood is called agarwood (Ba, 2010). At this moment, no other substances are similar as agarwood. Chemical substitutes are already available for perfume but do not come even close in emulating the natural product (Ali, 2006).

The identification of the small proportion of the trees having agar is difficult and destructive, which added greatly to the near-extinction of natural stands of trees (Blanchette, 2006). Also, large-scale logging operations have destroyed many forested areas where the Aquilaria trees are found. Thus, the current source of agarwood, the naturally-growing old-growth Aquilaria trees is becoming extinct (Hansen, 2000). Therefore, there is a growing need to cultivate Aquilaria trees as a renewable source for

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agarwood. Keeping above in view, the objective is to present a review of agarwood inoculation methods and its economical opportunities in Bangladesh.

1.1 Physical properties of *Aquilaria malaccensis*

There are fifteen species in the genus *Aquilaria* and eight are known to produce agarwood (Ng *et al.*, 1997). Recently it was mainly produced from *A. malaccensis*, *A. agallocha* and *A. secundaria* (Broad, 1995). *A. crassna* and *A. sinensis* are the other two members of the genus that are usually harvested. *Aquilaria Malaccensis* has been cultivated as part of the Agar plantation project in the eastern hill regions in the division of Sylhet, Chittagong, Chittagong Hilltracts and Cox's Bazaar forests of Bangladesh (A. Faruque, Chief Conservator of Forests and Management Authority for CITES, Bangladesh, in litt. to TRAFFIC Southeast Asia, April 2003).

Aquilaria malaccensis is a large, evergreen tree, up to 20 - 40 m tall (Adelina, 2004) and 1.5-2.5 m wide, with a moderately straight and often fluted stem bearing thin, pointed leaves, 5-8 cm long and with several parallel veins (Chakrabarty et al., 1994). Flowers are hermaphroditic, up to 5 mm long, fragrant and yellowish green or white which blooms at June. Fruits which appear in August, are green, egg-shaped

Figure 1 *Aquilaria malaccensis*. 1. leaf, 2. flower, 3. Fruit (Source: Wikipedia).

capsule, leathery covered with fine hairs, 4 cm long, and 2.5 cm wide. There are two seeds per fruit (Oyen and Nguyen, 1999; Sumarna, 2008).

1.2 Anatomy of *Aquilaria malaccensis*

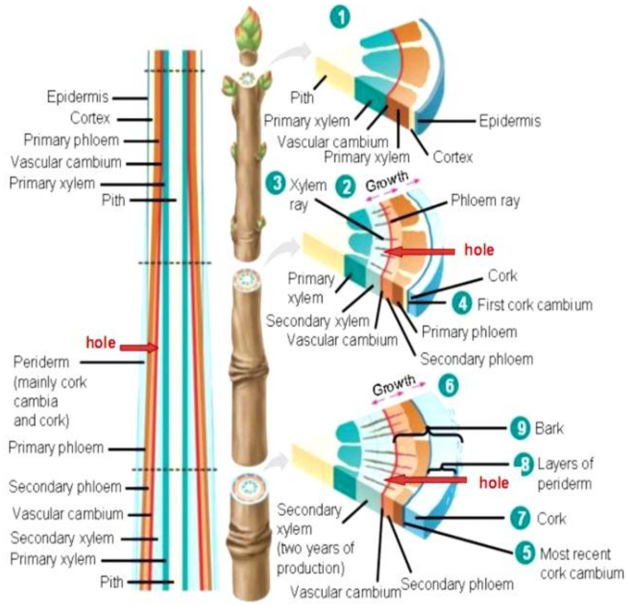

Figure 2 Cross section of *Aquilaria Malaccensis* (Source: Ba, 2015).

Aquilaria has a single layer epidermis which is composed of parenchymatous cells. This tree has an unusual anatomy and specialized cells within the xylem that produce the resin (Norsuzieana, 2009). Unlike most trees in the Angiospemae that produce phloem cells external to the xylem (growing out from the circumference of the cambium), *Aquikiaria* produce bundles of phloem cells throughout the xylem as well as in a layer external to the xylem. This means that the xylem (consisting of vessels, fiber and parenchyma cells) also contains groups of phloem cells called included phloem or interxlyary phloem of the diffuse (forminate) type. Centrally a pith region is located. When trees are wounded they respond by forming new wood cells by the cambium. These cells differentiate and close the wound with newly produced cells (Blanchette, 1992).

2 Agarwood inoculation methods

Aquilaria is unique in produceing phloem bundles within the xylem. This network of phloem and parenchyma produce and distribute the resin around affected areas as a tree defense reaction (Blanchette and Van Beek, 2005).

There are two kinds of inoculations.

i) Natural Inoculation

ii) Artificial Inoculation

2.1 Natural inoculation

In natural forest, only about 7% of the trees are infected naturally (Ng *et al.*, 1997). Formation of agar wood can be initiated by natural injuries (by ant, snails or fungus) and mostly obtained at the junctures of broken branches (Gauthier et al., 2015).

Figure 3 Natural inocular (Source: Wikipedia).

2.2 Artificial inoculation

Artificial inoculation technique developed and standardized in lab scale is found to be the most effective and reliable method for enhancement of agar wood formation. Some major methods are described here.

(a) Nailing method: Hammering of nails into the trunks has been used widely in the past, but the yield from this treatment is generally of poor quality which cannot meet the desired market demand (Persoon, 2007). Iron nails are placed into the trunk spirally in this method.

(b) Drilling method: A drill is usually employed to make holes in the trunks and main branches of mature trees (Akter et al., 2013). The drilled pores were placed in a spiral fashion on the tree from the ground line up into the crown. Wounds were placed 3 to 5 cm apart and inoculated with resinous agarwood powder or kept open to ease access of natural agents into the pores. Pores are checked and rewounded every 2-3 months (Blanchette, 2006).

Figure 4 (a) Nailing method, (b) Drilling method, (c) Aeration method, (d) Agar-wit method, (e) Burning-Chisel-Drilling method, (f) Fungi-Inoculation method, (g) Partly-Trunk-Pruning method, (h) bark peeling off (Source: Liu *et al.*, 2013).

(c) Aeration method: Aeration means a device inserted into the wound to prevent healing the pores and establish prolonged infection (Liu *et al.*, 2013). This treatment causes tree to respond both physical and chemical defense mechanisms. The aeration device may contain aeration holes in it, and/or it may contain grooves on its exterior surface. It may be made of plastic, bamboo, wood, or other organic material, or metal, such as iron. It may be about 2 cm in diameter. When inserted, the aeration device may extend out about 2 to 15 cm from the exterior of the tree (http://forestpathology. coafes.umn.edu).

This method may also involve applying a resin-inducing agent to cells surrounding the wound. It may kill live parenchyma cells around the wounded region of the xylem. It can be, for example, sodium bisulfate, NaCl, ferric chloride, ferrous chloride, chitin, cellobiose, iron powder or yeast extract. In particular, it may be 1:1:3 sodium bisulfate, Difco yeast extract and iron powder (Blanchette, 2006). Alternatively, or additionally, the resin-inducing agent may be an organism, such as an insect or microb, such as a fungus such as *Deuteromyota sp.*, *Ascomycota sp.*, *Basidiomycota sp*. This artificial induction could yield agarwood ten times faster than natural formation (Blanchette, 2006).

(d) Agar-wit method: The agarwood induced via Agar-Wit showed its characteristics similar to those of high-grade wild agarwood in terms of texture, chemical constituents, essential oil content, and ethanol-soluble extract content within 20 months (Zhang et al., 2012). Small holes deep into the xylem were drilled above 50 cm from the ground of the main trunk and the inducer was conveniently injected into the *Aquilaria* trees through a transfusion set. Due to water transpiration pull, the inducer was transported to the whole tree (root to branch) in 2 to 3 h and consequently led to internal wounds. Resinous wood formed around the wounds over several months. Substance like formic acid that have a low pH and NaCl that has a high pH both can disrupt live cells and induce large amount of agarwood (Liu *et al.*, 2013).

(e) Burning-Chisel-Drilling method (BCD): To prevent the invasion of environmental microbes, *Aquilaria* trees were induced to produce agarwood in a closed system by a typical physical wounding method, the burning-chisel-drilling (BCD) treatment (Zhang et al., 2014). The holes in the trunk from approximately 50 cm above the ground to the top of the trunk were achieved by a burning and red-hot iron drill bit (approximately 600 ℃ and 1.2 cm wide). The drilled holes, approximately 20 cm apart, were immediately sealed with sterilized paraffin wax to prevent microorganism invasion (Liu *et al.*, 2013).

(f) Fungi-Inoculation method (FI): Resin production in agar tree is the result of fungal infection (Oldfield et al., 1998) and it is in response to wounding (Beek and Phillips, 1999). The author also adds that fungal infection can increase resin production as a host response to increased damage due to fungal growth. *Aquilaria* trees are naturally infected by a variety of fungi including: *Aspergillus spp.*, *Botryodyplodia spp.*, *Diplodia spp.*, *Fusarium bulbiferum*, *F. laterium*, *F. oxysporum*, *F. solani*, *Penicillium spp.*, and *Pythium spp.* (Soehartono and Mardiastuti, 1997; Wiriadinata, 1995). Generally, 8 cm deep holes were made by a drill from 50 cm above the ground of a trunk. The vertical spaces between the holes were 20 cm, and in each horizontal line distributed two or three holes. The culture mediums were inserted as the bait into each hole, which was then wrapped by rubberized fabrics (Liu *et al.*, 2013).

(g) Partly-Trunk-Pruning method (PTP): Cuts of 2-4 cm wide and 3-5 cm deep were sawed along one side of the main trunk of an Aquilaria tree. The first cut was about 50 cm above the ground. The space between every two cuts was about 20 cm. It is similar with axing (Liu *et al.*, 2013). The characterization of wounded trunks originated from *A. sinensis* induced by BCD and Agar-Wit method has very high similarity with that of agarwood induced by PTP, both in chemical composition and vessel-occlusion formation (Zhang et al., 2014).

In some region, indigenous people peel off the bark to promote infection and harvest the chips of woods seasonally from live tree (Pojanagaroon and Kaewrak, 2003). Agarwood hunters in Papua New Guinea deliberately wounded agar trees in an attempt to stimulate agarwood production and they were able to harvest agarwood of B and C grades, three years after this treatment (Gunn et al., 2003).

Other factors, such as, age and diameter of a tree, environmental variation and genetic variation of *Aquilaria spp*. may also play an important role in agarwood formation (Ng et al., 1997). According to Chakrabarty et al., (1994), infected trees produce resin from the age of 20 years onwards and best yields are obtained from trees aged 50 years and over (Soehartono and Mardiastuti, 1997). But the Rainforest Project (TRP) in Vietnam has shown that agarwood formation can be occurred in cultivated trees from three years of age, by chemical analysis confirmation (Van Beek and Phillips, 1999). Research conducted in West Kalimantan Indonesia, showed that the yield of *Aquilaria* resin does not related with the diameter or timber volume, even when trees have similar indications of infection (Soehartono and Mardiastuti, 1997). Beside this, Agarwood formation is influenced by seasonal changes, rainy season accelerated agarwood formation faster.

3 Uses of agarwood

Medicine: Agarwood has been used for medicinal purposes for thousands of years, and continues to be used in Ayurvedic, Tibetan and traditional East Asian medicine (Chakrabarty et al., 1994; Fratkin, 1994). High-grade agarwood powder is used for aromatherapy (LaFrankie, 1994), and also used in the production of pharmaceutical tinctures (Van Beek and Phillips, 1999). It is prescribed in traditional East Asian medicine to promote the flow of qi, relieve pain, arrest vomiting by warming the stomach, and to relieve asthma (Hajar, 2013). Burkill (1966) reported that Malaysians used agarwood mixed with coconut oil as a liniment, and also in a boiled concoction to treat rheumatism and other body pain.

Perfume: The use of agarwood for perfumery extends back several thousand years (Chaudhari, 1993). Both agarwood smoke and oil are customarily used as perfume in the Middle East (Chakrabarty et al., 1994). Although, several commercial synthetic agarwood fragrance compounds are available, they can produce only low-quality fragrances, owing to the chemical structure of natural agar oil (Van Beek and Phillips 1999). Agarwood incenses have also been used as a fragrance in soaps and shampoos (Schippmann, 2001).

Incense: Agarwood incense is burned to produce a pleasant aroma, its use ranging from a general perfume to an element of important religious occasion. It is highly psychoactive and is used for incense (Qi et al., 2005). Taiwanese consumers purchase agarwood for the manufacture of incense sticks, which are used in prayers during many traditional festivals and ceremonies to bring safety and good luck (TRAFFIC East Asia-Taipei, in litt. to TRAFFIC International 1, 2 May 2000). In Japan, it is considered by many to be sacred and is used to anoint the dead. In Buddhism, it serves as a major ingredient in many incense mixtures, and it is considered to be one of the three integral incenses, together with sandalwood and cloves (Barden et al., 2000).

4 Economic values

The value of first-grade agarwood is extremely high. It is sold in the form of woodchips, wood pieces, powder, dust, oil, incense ingredients and perfume for several thousand US dollars per kilogram (LaFrankie, 1994; Barden et al., 2000; Gunn et al., 2004; Compton, 2007) which varies with geographical location and cultural deposition. Agarwood chips start at $30 per kilo up to $9,000 per kilo depending on how much resin is inside the chips (Babatunde, 2015). First-grade agarwood is one of the most expensive natural raw materials in the world. Agarwood oil fetches similarly high prices (Agarwood “Wood of Gods” International Conference, 2003). When agarwood chips are processed into oil, the agarwood oil was sold at US $ 30,000 per kg (Nanyang Siang Pau, 15 August 2005). The current global market for Oud oil and other related agarwood products is estimated to be in the range of US$ 6 to 8 billion (Akter et al., 2013) and the major industry buyer of Oud oil, is expected to exceed US $ 36 billion in 2017 (http://www.ouddh.com/?cid

=2065877). For Integrated cropping - Set up 1,000 ha plantation for agarwood and banana production internal rate of return (IRR) and benefit-cost ratio (B/C ratio) are 54.85% and >1 (3.30) respectively (Mamat et al., 2010).

4.1 Bangladesh perspectives

In collaboration with Research and Evaluation Division and tea estate of BRAC (Bangladesh Rehabilitation Assistance Committee) a project on agarwood plantation has been initiated at Kaiyachara Tea Estate, Fatikchari since July 2007 (Akter and Neelim, 2008). Under the supervision of BRAC tea estate Kaiyachara division a 17 acre plantation has been created, where 83,400 agar seedlings have been planted between August and October 2007. Also, about 700,000 agar seedlings have been planted in two nurseries, namely 'Kaiya' and 'Sirgasia', at Kaiyachara tea estate. In an addition, there are several small scale and personal agarwood plantations in Modhupur (Mymensingh), Birisiri, Haluaghat (Netrokona), Sylhet, Habiganj and Chittagong Hill Tracks (Alam, 2004; Islam, 2013). Initially the BRAC tea estate plans to plant 50 acres of land with agar plant, after which agarwood harvesting would take place after 12 years. Assuming 90% survival rate and 2 kg premium quality agarwood production per plant, the estimated investment related to plantation would be \$ 1.82 million and total return would be \$ 761.34 million with the rate of return 41,861% (Akter and Neelim, 2008). Along with, this high rate of return, the establishment of this plantation would be significant in terms of the environmental conservation of this endangered species, as well as, provide a carbon sink to reduce green house gases.

There are about 100 enterprises producing agar wood and agar oil in Bangladesh (Abdin, 2014). Local entrepreneurs are claiming that this is a 100% export oriented sector based on local raw materials and using indigenous technology. They are exporting about US$ 62.5 to 125 thousand per year (www.smef.org.bd).

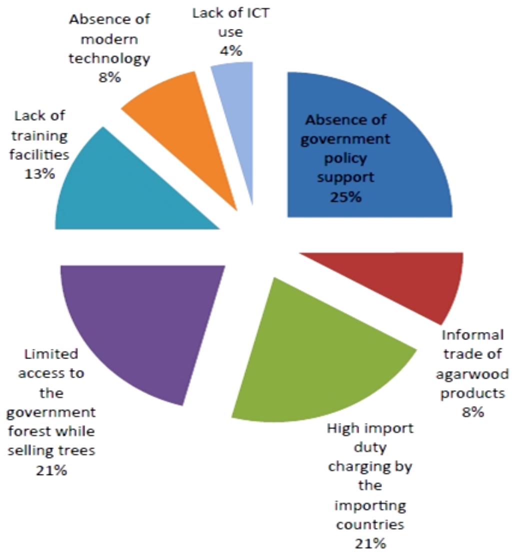

Figure 5 The most severe barrier toward development of agarwood industry in Bangladesh (Abdin, 2014).

If the government of Bangladesh and relevant agencies may consider declaring agar wood as a thrust sector in the National Industrial Policy (while revising) and take necessary steps to overcome the barriers, then this will open a new multidisciplinary opportunity for the economy of Bangladesh.

5 Conclusions

Based on finding of this review, artificial inoculation methods would produce more agarwood than natural inoculation because they have been practiced successfully in agarwood exporting countries during last few decades. It would be preferable to consider artificial inoculation to get better quality and yield, and to change the economic standards of agar cultivators of Bangladesh. The ventures are needed to search new plants, selection of inoculars, and induction methods. Initiation of multidisciplinary approach with the experts of forestry, mycology, biochemistry, and microbiology is necessary to achieve the goal.

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