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DEVELOPMENT OF AGAR (*Aquilaria malaccensis*) CULTIVATION, PROPAGATION TECHNIQUE AND ITS POTENTIALITY AS AGROFORESTRY COMPONENT IN BANGLADESH: A REVIEW

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Abstract

Investigating present status of agar (*Aquilaria malaccensis)* cultivation in Bangladesh is necessary for sustainable economic development. The objective of this study was to document the existing agar cultivation technology especially modern technique for propagation and agarwood formation as well as potentiality as agroforestry component in Bangladesh compared to global standard. The paper was based on literature review and field experiences from Sylhet and Moulvibazar districts of Bangladesh. Since many research works were done on these issues but all are not available to the public in a systematic manner to date. This review study revealed that there was no modern artificial wounding technique available rather than conventional nailing technique, which was major reason behind the low quality and quantity of agarwood production in Bangladesh. This review paper also reported the latest potential technique of agarwood formation namely CA kits (Cultivated Agarwood Kits). In addition, agar is reported as potential agroforestry component in Bangladesh for its edaphic and climatic factors. There was no other modern technique of propagation except conventional propagation by seed in Bangladesh. Introduction of modern propagation and wounding technology eventually would help to achieve the SDGs through its all three dimensions (economic, environmental and social). This high valued crop would benefit rural people and contribute greatly to the economy of the region.

Keywords: Agar, propagation, induction technique, agroforestry.

Introduction

The *Aquilaria* (Thymelaeaceae) tree is a well-known important agarwood-producing genus, which is endemic to the Indomalesia region (Lee and Mohamed, 2016). It is a precious non-timber product of tropical tree origin (Rasool and Mohamed, 2016). Due to its aromatic fragrance, it is used as a raw material in making incenses and perfumes (Rasool and Mohamed, 2016). It has high commercial value but the tree source is severely endangered due to indiscriminate felling. Over the years, demand for this scarce material has increased tremendously (Rasool and Mohamed, 2016). This genus is currently protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulation and the International Union for Conservation of Nature (IUCN) Red List due to its heavy declination in the natural population in various sourcing countries (Lee and Mohamed, 2016). To date, there are 21 recognized *Aquilaria* species recorded, of which 13 are reportedly fragrant resin producers, and the status of the remaining eight *Aquilaria* species is yet to be investigated (Lee and Mohamed, 2016). According to CITES (2004), among the 15 species of *Aquilaria* (i.e., *A. apiculata*, *A. baillonii*, *A. banaense*, *A. beccariana*, *A. brachyantha*, *A. cumingiana*, *A. filaria*, *A. hirta*, *A. khasiana*, *A. malaccensis*, *A. microcarpa*, *A. rostrata*, *A. sinensis*, *A. subintegra* and *A. crassna*), the agarwood-producing species *Aquilaria malaccensis* existing in Bangladesh is found in the eastern hill regions in Sylhet division, Chittagong, Chittagong Hill Tract (CHT) and Cox's Bazar. But no population estimates are available for *Aquilaria agallocha*. However, as *Aquilaria agallocha* is sometimes considered a synonym of *Aquilaria malaccensis*. Hayder *et al*. (2005) reported that agar is one of the most promising non-timber forest products (NTFPs) of Bangladesh. Hossen and Hossain (2016) also reported that

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Bangladesh can earn more than Tk. 100 crore annually by developing its agarwood sector and exporting agar products abroad.

To overcome demand and conserve the sources, much effort has drawn toward cultivating the tree species in sourcing countries (Rasool and Mohamed, 2016). Since the ever increasing international demand for agarwood cannot be satisfied by limited natural stocks of *Aquilaria* trees, there is a need for mass cultivation of the trees to relieve the pressure on its natural population (Rasool and Mohamed, 2016). Not only planting better genotypes can help, but one has to extend modern techniques that are efficient at inducing agarwood and practical for application in plantation setting (Rasool and Mohamed, 2016). A number of studies have been conducted on the socio-economic role of agar plantation. Akter *et al.* (2013) reviewed that artificial induction is not a new story but yet to be made known and available in the country. Chowdhury *et al*. (2016) reported that 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. Chowdhury (2014) evaluated a novel technique, called the aeration method, for producing agarwood in cultivated *Aquilaria* trees.

Ahmed (2010) surveyed the agar production in Haluaghat upazila of Mymensingh district and Barlekha upazila of Maulivibazar district to investigate plant growth, number of fruits, agar cultivation process, and agar production. Hayder *et al*. (2005) reported that no major extension program has so far conducted by governments or other agencies in Bangladesh. Abdin (2014) reported development barriers of Agar sector in Bangladesh. Proper regulatory support from the government could play a vital role to make it one of the major foreign currency earning sectors for Bangladesh. Rahman *et al*. (2015) reported that the population of agar tree is rapidly declining in natural forests in Bangladesh, and the species is now being planted in government-owned degraded forest sites as well as privately owned homestead forests. They also found that the traditional management practices were adapted mostly based on indigenous knowledge and technology to manage agar plantations. Islam *et al.* (2014) investigated the low cost agar oil extraction system for agar tree growers in Bangladesh. Rahman *et al.* (2015) reported that agar trees were planted in monoculture and block plantations in Maulvibazar district. Uddin *et al.* (2008) reported that there is a lack of up-to-date information of technology. However, little is known about the latest artificial wounding techniques of agar and its potentiality as agroforestry components. Therefore, the objective is to present a review of propagation technique, modern artificial wounding methods, potentiality of agar plant as agroforestry component and their implication in Bangladesh.

Materials and Methods

To assess the current state of the research on agar cultivation, a review of the existing journal literature, books, report, blogs and newspaper were carried out. A keyword search in the google, google scholar, web of science database (www.thomsonreuters.com/web-of-science) and a full-text search of the Science Direct (www.sciencedirect.com) database using Seoul National University Library Proxy Server was carried out. Information was also collected from GO and NGO's by personal communication.

Soil and environmental suitability for agar cultivation in Bangladesh

Aquilaria species grows naturally in all ecological zones and on a variety of soils under wide climatic condition (Table 1), including those that are rocky, sandy or calcareous, well-drained slopes and ridges and land near swamps. However, significant mortality rate were reported 3 - 4 years after plantation in Kaiyachara Tea Estate, Fatikchari seemingly due to water logging (Akter and Neelim, 2008). Planting on sloping land is thus recommended for agar (Jansen, 2003). The precipitation normal in Sylhet division ranges from 2351 mm to 4048 mm (Talucder *et al.*, 2015). In addition, average temperature and soil condition are also well suited for agar cultivation in this region. *Aquilaria* is first growing trees and in areas with adequate moisture, can achieve 10 cm DBH in 4 to 6 years (Blanchette *et al.*, 2015). They are especially suited for the hill ecosystem of northeastern India. In Assam, as well as in Northern Bangladesh around the Sylhet area, *Aquilaria* have been successfully planted in plantations (Blanchette *et al.*, 2015).

Distribution of agar garden in Bangladesh

Among the total area of Bangladesh, agricultural land makes up 65% of its geographic surface, forest lands account for about 17%, while urban areas are 8%. Water and other land use comprise the remaining 10%. The total forestland includes classified and unclassified state lands and homestead forests and tea/rubber/agar gardens. Actually, about 8.37% of the total land is found with tree cover. Of this, about 6.5% belongs to the state owned Forest Department, and the rest 1.87% is privately owned village groves scattered throughout the whole country

(Akhtaruzzaman, 2006). But, still there is lack of appropriate statistics of area under agar cultivation in Bangladesh to date. Area and location under the government as well as private agar garden are presented in Table 2 and Table 3. Besides this, Forest Department of Bangladesh has recently successfully established approximately 7,085 ha of agar plantations in denuded forest areas of Sylhet, Chittagong and CHT (Hossen and Hossain, 2016). Therefore, currently, the area under the agar garden is so far about 10,095 ha in Bangladesh.

Table 1. Suitable climatic and soil factors for the cultivation of *Aquilaria* species

Climatic variables and soil factors	Range of values
Altitude range	29 - 1000 m
Mean annual rainfall	1500 - 6500 mm
Mean annual temperature	22 - 28ºC
Mean maximum temperature of hottest month	22 - 40ºC
Mean minimum temperature of coldest month	14 - 22ºC
Absolute minimum temperature	5ºC
Soil texture	light; medium
Soil drainage	free
Soil reaction	acid; neutral
Special soil tolerances	shallow; other

Source: Adopted from Akter and Neelim, 2008

Table 2. Area under agar cultivation at different regions of Bangladesh

Location	Area (ha)	Managing entities	Plantation period	Reference
Kaiyachara Tea Estate, Fatikchari	6.9	The Bangladesh Rural Advanced Committee (BRAC)	July, 2007	Akter and Neelim (2008)
Karnafuli tea estate	0.6	BRAC	2004	Akter and Neelim (2008)
Buffer zone of the Kaptai National Park	283.0	Participants of social forestry programe	2007-2012	Rahman (2013)
Charaljani and Keochia research stations in Chittagong	2.3	Bangladesh Forest Research Institution (BFRI)	-	Rahman *et al.* (2015)
Government agar garden in Denuded forest areas of Sylhet, Chittagong and CHTs	1217.0	Forest Department (FD)	1999-2011	Novel (2017)
121 Privately owned agar garden in Sylhet Division	>1500.0	Private owner	1999-2011	Novel (2017)

Propagation and Plantation

Agar is propagated by seeds, which are available in the month of June-July (Anonymous, 2004). Propagation must take place when seed is mature. The germination of seed is epigeal, therefore, special care should be taken in nursery management. They are first germinated in sand beds and then transferred to poly bags (Anonymous, 2004). This must be done very soon after the fruit has opened and the seed exposed since seed of *Aquilaria* have a short time period (7-10 days) for viability since recalcitrant features of its seed. Successful seed storage is difficult and loss of viability occurs very quickly once seeds are exposed to the environment. However, with good planning, proper management and modern nursery practices, *Aquilaria* seedlings can be produced in large numbers (Blanchette *et al.*, 2015).

From 25 days onward when the cotyledons just drops down the seedlings are transplanted carefully to poly bags arranged under temporary shade. Normal management practices should be adopted. After planting young seedlings in poly bags, they are arranged in bed supported by bamboo poles around. At monthly interval the shifting of bags should be done to prevent the penetration of roots into the soil. Shifting of seedlings should be followed by light

watering to avoid wilting due to disturbances in the root system. Root trainer may be used successfully (Anonymous, 2004)

Table 3. Number of private agar garden at different upazila in Sylhet division (Novel, 2017)

Name of the upazila	No. of agar garden	District
Barlekha	111	Maulvibazar
Kulaura	6	Maulvibazar
Komolgonj	2	Maulvibazar
Sylhet Sadar	2	Sylhet
Total	121	Sylhet division

Agar is a long-term plantation crop. A profitable plantation may be of 15 years cycle or more. The short cycle plantation yields only essential oil or 'agar attar' of low quality (Boya oil). The plantation may be planned in two ways: (a) planting at wider spacing along with some suitable intercrops and harvesting at the end of the crop cycle. (b) Planting at comparatively closure spacing and harvested at 2 - 3 phases. In the second approach about 8 - 10 years of planting about 40 % selected trees may be harvested with a view to thin out the plantation for better growth and development of the remaining trees and also to get a substantial income (Anonymous, 2004). Agar trees require 2 × 2 m spacing for rapid growth and development (Zabala, 1989).

Potentiality of Agar plant in the Agroforestry

Ha and Nghi (2011) reported that agar has been widely grown in the agroforestry farms in Vietnam since the 1990s. They found that agar is intercropped with cassava, sweetpotato and oil palm in agroforestry systems in Vietnam. Agar can also be intercropped with *Acacia*, upland rice and pineapple. Some farms in Vietnam also integrate agarwood and fruit trees in their home gardens. It can be intercropped with a combination of agricultural crops and fruit trees such as upland rice, cassava, beans, sweetpotato, yam, banana, pineapple, jackfruit and many more. Aside from its essential oils, agar is also grown to provide shade. They recommended that agar in agroforestry systems should be promoted to fully harness the potentials of the tree species. At the same time, oil processing technologies should also be promoted as a livelihood program for farmers and rural communities. Saikia and Khan (2012) reported that low input needs and flexibility in site requirements as well as suitability for intercropping make agar a preferred cash crop in the home gardens of upper Assam. They showed that agar based home gardens in upper Assam are financially rewarding and can generate significant amount of money for sustaining the economy of the region. In North eastern region of India, Patchouli based agroforestry model was found promising since the patchouli plants are highly suitable for planting in shade under the agar tree species (Gera and Bhojvaid, 2013). Kunio and Lahjie (2015) reported that the future of forest industry would be better diverted to the non timber forest products by cultivating vanilla and agarwood with agroforestry system. It because in economically was feasible to cultivate as a model of sustainable forest at East Kalimantan Province. In Bangladesh, Rahman (2013) also reported the agar as potential component of participatory social forestry programmes in the buffer zone of the Kaptai National Park during 2007-2012 to cater to the local demand for forest products, to reverse the process of ecological degradation, and to enhance the food security, nutrition and socio-economic circumstances of rural people. Blanchette *et al.* (2015) reported that *Aquilaria* has been grown with rubber, teak, banana and even oil palm in Southeast Asia.

The good capacity for pollarding and coppicing of agar has made it suitable to fit in agroforestry (Anonymous, 2004). Agar tree could successfully be introduced in Social Forestry and also in Afforestation Programme (Anonymous, 2004). Tea growing situation is also ideal for agar tree. The increasing demand of agarwood, it is being introducing as shade tree in tea plantation (Blanchette *et al.*, 2015).

Agar tree is suitable for growing on field boundaries and for dividing whole plot into sub-plots. Not only this, agar tree is also grown on borders of gardens, school compounds, office compounds, parks and residential sites. The canopy of Agar tree is such that it allows sunshine penetration partly. Thus, it can be planted in field boundaries, bunds etc., without affecting the field crops. Besides, agar tree has been successfully grown for strip planting along banks of ponds, tanks, canals and roads. In hilly areas / tillas , it can be planted on poor soils on hill slopes, tilla tops. They help in reducing soil erosion and land sliding caused by rushing water during rainy season.

Artificial Induction Technique

***Customary induction*:** Over the past years, many techniques have been tried to induce agarwood (Ng *et al.*, 1997). Agarwood induction, as perceived by local people, on trees growing in the natural environment, happened in old trees that had been stroked by lightning or attacked by animals, insects, or microbes. The formation is usually in proximity to wounded or decaying parts of the trunk. Initially it was thought that formation of agarwood takes place only in the stem or the main branches. It happens in roots and twigs as well. Various conventional methods have been developed e.g., Nailing Method, Drilling method, Partly-Trunk-Pruning Method (PTP), Burning-Chisel-Drilling Method (BCD), Fungi-Inoculation Method (FI) etc. which are briefly summarized as follows:

***Nailing method*:** In this method, wounding agarwood tree by hammering of nails into the trunks often with hundreds or even thousands of nails put into each tree. Iron nails are placed into the trunk spirally in this method. This process is extremely labor intensive and takes a great deal of time to carry out. After many years, each nail wound produces a slight amount of low quality resinous wood. In addition, agarwood yielded from this treatment is generally of inferior quality and cannot meet the desired market demand (Persoon, 2007). In the Moulvibazar district of Bangladesh, still farmers use pegging of iron nails in tree trunks as a means of artificial wounding (Rahman *et al.*, 2015) which is considered as the main reason behind the low quality and quantity of agarwood production.

Fig. 1. Nailing Method (Blanchette *et al.*, 2015)

Drilling method: Drilling on the stems, roots and large brunches is a common method. 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. Wounds were kept open to ease access of natural agents into the pores. Pores are checked and rewounded every 2 - 3 months. This was done whenever the wounds appeared to have any wound closure (Blanchette, 2006).

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).*

Burning-Chisel-Drilling method (BCD): 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 (1.2 cm wide). The holes on the trunk of each tree were approximately 20 cm apart (Liu *et al., 2013)*

Fungi-Inoculation method (FI): From 50 cm above the ground of a trunk, holes of approximately 8 cm deep were made by a drill. The vertical space between the holes was 20 cm and in each horizontal line distributed two or three holes. The culture medium *Melanotus flavolivens (B.* etc*)* Sing was inserted as the bait into each hole, which was then wrapped by rubberized fabrics (Liu *et al.*, 2013).

(a) Drilling method

(b) Partly-Trunk-Pruning Method

(c) Burning-Chisel-Drilling Method

(d) Fungi-Inoculation Method

Fig. 2. (a) Drilling method, (b) Partly-Trunk-Pruning Method, (c) Burning-Chisel-Drilling Method, and (d) Fungi-Inoculation Method (Liu *et al*., 2013)

These methods are hand-down traditions and have been practiced sustainably on trees growing on individual and ancestral lands and in natural forests.

Modern Artificial Induction

Aeration Method: In the present method, the aeration means may be a device inserted into the wound to prevent healing the pores and establish prolonged infection. The aeration device may contain aeration holes in it and/or it may contain grooves on its exterior surface. The aeration device may be made of plastic, bamboo, wood, or other organic material, or metal, such as iron. It may be about two cm in diameter. When inserted, the aeration device may extend out from the exterior of the tree such as about two to fifteen cm from the exterior of the tree. This method may also involve applying a resin-inducing agent to cells surrounding the wound. This resin-inducing agent stimulates resin production in the tree (Blanchette, 2006).

Fig. 3. Aeration Method (Agar-Wit) (Liu *et al*., 2013)

Whole-tree agarwood inducing technique (Agar-Wit): Whole-tree agarwood inducing technique (Agar-Wit), applies simple and cheap transfusion sets through which agarwood inducers are injected into the xylem part of the tree (Zhang *et al*., 2012). The inducer is liquid form and is related to the whole body of the tree due to water transportation causing agarwood to form in every wood part. 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*).* Agarwood yield per tree reached 2445 - 5861 g, which is 4 to 28 times as high as from existing agarwood inducing methods. Further, the agarwood derived from Agar-Wit induction has produced higher quality compared with the existing methods, and similar to that of wild agarwood.

Fig. 4. Whole-tree agarwood inducing technique (Agar-Wit) (Liu *et al*., 2013)

Fig. 5. Agarwood inducement kit called "CA kit". New technology that has a proven record of success is now available to produce agarwood in young plantation trees and kits have been developed with all the materials needed to treat trees (Blanchette *et al.*, 2015)

Cultivated agarwood kits (CA-Kits): Rassol and Mohamed (2016) reported that CA-Kits pioneered by Blanchette and Heuveling van Beek (2009), where tubes are placed in the tree trunk as a mean to introduce microbes and to arouse production of the defense compounds by the tree naturally. Blanchette *et al.* (2015) reported that CA-Kits technology has a proven record of success and has been used in *Aquilaria* plantations located in Vietnam over many years producing fine quality agarwood that is sold worldwide. The same methods can be used in Mazoram or other States in India, Bangladesh and other hill country sites to have a successful agarwood production program. The hill agro-ecosystems of Mizoram, other regions of Northern India, Bangladesh and Myanmar are ideally suited to grow *Aquilaria* and could be an excellent producer of cultivated agarwood. However, Rahman *et al.* (2015) reported that agar farmers in the Sylhet division are not aware of the modern techniques of artificial wounding. In addition, there are no government agencies or NGOs to help them develop a suitable low-cost technique for artificial wounding.

Conclusion

Agar tree is one of the promising components for diversified agroforestry systems in Bangladesh especially in Sylhet region due to its favorable climatic and edaphic conditions. There are major challenges to date which

includes scarcity of high quality seedlings, lack of modern silvicultural practices and absence of modern artificial wounding technique. One of the strategic remedies would be the employment of a new technology for artificial wounding such as Cultivated Agarwood Kits (CA-Kits) which provides higher yield as well as quality compared with the other existing techniques with reduced labor costs. Understanding agarwood induction and formation, specifically at molecular level, is essential for improving the production in living trees.

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