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CONTENTS

Potential and scope of Agarwood (*Aquilaria malaccensis* lamk.) cultivation in India

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ABSTRACT: *Aquilaria malaccensis* (Thymelaceae) is a resin-producing tree and is commonly known as Agar or Sasi. In the North Eastern regions of India, the cultivation of Agarwood is extensively practiced, and a huge opportunity exists to promote the cultivation of Agarwood in the other regions of the country. Agarwood is used in various commercial products ranging from perfumery to religious functions. It has demonstrated immense potential in enhancing farm income and generating employment opportunities for the local people. Despite the achievement of good success in Agarwood cultivation, ample opportunity exists to develop agro-technology of cultivation, produce quality planting material, device management operations of plantations, and identification of elicitors for early inducement of agar oil. The price of natural resin is very high but only 1-2 % of the trees produces agar, while almost all artificially induced trees produce agar but their price is low, which is one of the major challenges in the Agarwood industry. Biotechnological techniques, such as, the use of microbes and microbial enzyme systems can contribute in terms of the value addition in agar oil. The artificial regeneration and plantation have been encouraged to promote the conservation of *Aquilaria* species at large, however; farmers face difficulty from associated abiotic and biotic stressors; those are affecting the overall survival rates of plants. Therefore, practicing scientific cultivation and adopting proper induction techniques in Agarwood can make a huge benefit to farmers, stakeholders, and industries.

Key words: *Aquilaria malaccensis,* agarwood oil, artificial induction, employment, opportunity

The genus *Aquilaria* belongs to the angiosperm family "Thymelaeaceae", and is indigenous to the Indo-malayan province (CIFOR, 1996). To date, 21 Agarwood species have been identified and out of which 13 are known to produce Agarwood. Unfortunately, the destructive harvesting has severely exploited the wild populations of *Aquilaria* species (Lee and Mohamed, 2016), resulting in a sharp decline in the number of species in the wild. The genus has been protected and designated as an endangered species by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES (Buitron and Mulliken, 2003). The greater demand for Agarwood in the international market as well as the reduced supply from the wild has caused an increase in the price of Agarwood (Liu *et al.*, 2017). *Aquaria* tree is a source of highly-priced Agarwood due to which this species is extensively cultivated and farmers earn huge profits from this tree (Naef, 2011).

Highly prized Agarwood is dark-colored resinous heartwood, known as "Gaharu" in Southeast Asia, "Oud" in the Middle East, "Chen Xiang" in China, "Jinkoh" in Japan, and "Agar" in India (Abdin, 2014 and Jim, 2015). The stem injury followed by an invasion of fungus is a process involved in the production of Agarwood from *Aquilaria* tree (Lin *et al.*, 2010). Once an injury occurs in trees either naturally or artificially, the trees exude the resins to protect themselves against the natural or induced injury (Pojanagaroon and Kaewrak, 2006). Over the period, a volatile compound is produced from the resin which later on forms Agarwood (Tajuddin and Yusoff, 2010). Agarwood has long been utilized for religious rituals, aromatized food ingredients, and therapeutic scents. It serves as a natural relaxant, reliever, traditional remedy, and flatus-relieving in Chinese medicine (Compton and Ishihara, 2006 and Antonopoulou *et al.*, 2010). Agarwood is highly sought after on a global scale as a raw ingredient for incense and perfume and medicinal uses, especially in the Arab world and East Asia. In recent decades, the increase in the incomes of the consuming countries has resulted in a mismatch between the demand-supply of Agarwood (Barden *et al.*, 2000; Blanchette and Van, 2005). Based on quality, the price of Agarwood ranges from approximately $25 to $6,000 per kilogram for wood chips and US$ 10,000/kg for the actual wood. The volatile oil of Agarwood could be worth up to 30,000 dollars per kg. Agarwood is considered to have an annual market worth between US$6 and US$8 billion, but many of the trades are not counted in for this assumption (Sustainable Agarwood Investment, 2013).

Due to the lack of natural Agarwood formation in trees and even some trees that don't produce Agarwood, artificial Agarwood forming techniques have been developed to induce the formation of agar in these trees. Chinese historians began attempting to artificially create Agarwood at least as far back as the year 300 E.C. They noticed that injury leads to the accumulation of resin and change in internal tissue colour within one year (Wei *et al.*, 2010). In addition to manual wounding, the use of chemicals, insect, and microbe procedures are also becoming more widespread in the Agarwood industry. Despite the advantages and disadvantages of each method, all of these induction techniques have good potential to initiate the formation of Agarwood in trees (Bose, 1938).

Description

The Agarwood tree also known as Agar, Akyaw, Sasi, Wood, and Malacca Eaglewood, is a tropical little tree that attains 35-40 m of height and 10-13 m of thickness (Gunn *et al.*, 2004). Silky new shoots, and long and sword-shaped leathery leaflets that are repeatedly placed, and a pale, thin and smooth stem are all features of this plant. It has velvety, egg-shaped fruits and clusters of white blooms. seeds and bark are the only culinary portions and curry dishes are flavoured with them. Among all *Aquilaria* species, the *Aquilaria malaccensis* species is a significant producer of Agarwood resin which is used in aromatherapy and incense. A fungus called *Phaeoacremonium parasiticum* parasitize and infects a tree, resulting in the production of resin substance in the *Aqilaria* tree (Crous, 1996).

Distribution

Aquilaria malaccensis is the main species of genus *Aquilaria* distributed in different parts of world, primarily in the Southern or South-East Asian countries. In India, it occurs mostly in the foothills of Northeastern region (Assam, Meghalaya, Nagaland, Mizoram, Manipur, Arunachal Pradesh and Tripura) and West Bengal. The escalating agar demand, illegal harvesting, poor monitoring, illegal trade expansion, etc. are major factors responsible for the decline in the species population, leading to the *A. malaccensis* on the verge of extinction in its natural habitat. It has been officially listed as critically endangered on the IUCN red list (Oldfield *et al.*, 1998).

Climate and Soil

Aquilaria malaccensis thrives well at elevations between 200 to 700 meters in lowland and moist tropic regions. It prefers annual precipitation ranging between 150–650 cm and annual maximum and minimum temperatures ranging between 21–29°C and 14–21°C, respectively (Afifi,1995; Keller and Sidiyasa, 1994 and Wiriadinata, 1995). It grows well on sandy loam soil made from sandstone but favours heavier soils made from gneiss and other metamorphic rocks (Ridwanti *et al.*, 2020).

Regeneration

The primary Agarwood producers are only three species of *Aqualaria* that are likely to be related and are identified by the size of their calyx lobes. The Indo-Chinese plant *Aquilaria crassna* has 12 to 15 mm long lobes, while, the Indian and Malaysian species *Aquilaria malaccensis* contains 2 to 3 mm long lobes. China's *Aquilaria sinensis* species consists of 8mm long lobes. The *Aquilaria* trees grow quite slowly which leads to the attainment of desirable growth after a long period. For example, a 67 year old plantation in Malaysia attained only 26 to 28 m in height and 37 to 40cm in diameter. Some reports showed that species attained 4 to 5m in height and 28 to 30cm in diameter after 8 years. Similarly, 80 years old mature trees can attain 25 to 30 meters height and 55 to 70 cm breast height diameter. Flowering and fruiting may begin in a 7 to 9 years old tree. In these species, the seed production is very scanty, and good seed production occurs rarely and during the latter period, a tree on average may produce 1.6 kg of seed. Even though resin formation starts at the age of 20, only tree aged 50 years or even older produces the finest quality Agarwood (Chakrabarty *et al.*, 1994).

A pathological process occurs naturally in hole or in primary branches of trees during Agarwood formation. Although, the process involved in the association of fungus with trees is still not completely understood. The infection is frequently linked to the damage caused by bore or drilling insects. It is considered that a fungus attacks and damages the tree and the Agarwood is formed when a second fungus infects a tree. *Cytosphaera mangiferae* is the fungus known to be participating in the formation of Agarwood in the species, whereas *Melanotus flavorings* are also known to have an almost related function in *Aquilaria* species (Gong and Guo, 2009 and Zhang *et al.*, 2014).

Nursery Techniques

Mature fruits, green in colour are considered collected for extracting the seed. An average-sized tree produces approximately 1500 to 2000 seeds per year, though the production of seeds can vary considerably among the differently aged trees (Uma, 2012). After two days of drying in the shelter, the fruits burst and release their seeds (Fig. 1). The seeds remain viable for only one month; therefore, immediate sowing is required for obtaining optimum germination. seeds are sown at 0.5 cm depth in nursery beds containing a mixture of soil, coarse aggregates and animal waste under partial net shade (Srivastava and Behl, 2002).

seed starts sprouting after 11 to 13 days and germination is completed after 30 days (Tabin and Shrivastava, 2014). Germination rates of the freshly collected seeds are around 60%, which drops to 40% after 7 days and to 4 to 5% after 21 days in storage. Insect attack is a major problem observed at the seedling stage. After 40 to 45 days of germination, when the newly emerged seedlings become 3 to 5 cm tall, they are pricked out into containers and kept inside the shelter. One-year-old seedling attains 28 to 38 cm height, at that stage seedlings become ready for transplanting. In some regions, bare-rooted seedlings have been successfully transplanted.

Inter-cropping

Aquilaria malaccensis can be grown in a variety of soil types and on marginal terrain, but it prefers well-drained soils. Species are hardy and grow rapidly, and attain 10 cm DBH in 5 to 7 years in areas

Fig. 1: Flowering and seeds of *Aquilaria malaccensis*

receiving good precipitation (Hayder *et al.*, 2005). Few farmers in India have already initiated Agarwood cultivation either in pure plantation or in integration with various crops, like *Camillia sinensis* (Tea), *Pogostemon cablin* (Patchouli), *Rauvolfia serpentine* (Sarpagandha), Jatropha (Physic Nut), *Piper longum* (Pepper), *Ananas comosus* (Pineapple), *Curcuma longa* (Turmeric), *Areca catechu* (Arecanut) and with many more such crops. Integrated cultivation of Agar trees with other crops gives additional and huge returns to the farmers (Chaudhari, 1993).

Planting Entire Transplants (ETPs)

The 10 to 12 months old seedlings of *Aquilaria malaccensis* attaining 30 to 35 cm height can be transplanted (Fig.2). The best time to transplant ranges from April to June and during the rainy season and is planted at 3mx3m spacing (BFRI, 2011). In some places, bare-rooted seedling transplanting has also achieved great success. After 90 days of transplanting, spading and concurrent weeding are required to maintain proper growth and development (Blanchette *et al.*, 2015).

Applications of Manure and Fertilizers

During planting, the application of fertilizer such as rock phosphate (CIRP) is necessary to improve fertility and reduce nutrient deficiencies in soils which ultimately maintain plant growth. The amount of fertilizer to be applied depends on the size and age of the plants which must be planned after observing the condition of the plant (Rodrigo, 2005). As a basic rule, during the first year, a combination of organic fertilizer and chemical fertilizer in the form of NPK in the ratio of 8:8:8 should be applied @100gram/sapling. During the second to fifth years' fertilization any inorganic fertilizer with a 12:12:12 + TE ratio, should be applied @ 100g to 200g per sapling (Kauffman *et al.*, 1995 and Webb *et al.*, 1997). The conditions and growth of the tree determine the frequency and application of fertilizer dose.

Fig. 2: ***Aquilaria*** **seedlings in the nursery stage**

Plant Protection Measures

Aquilaria malaccensis trees are subjected to a variety of diseases and pests (Lee, 2011). Under nursery conditions and throughout their early growth in field conditions, care should be taken to maintain a clean environment for the seedlings. There have been no incidents of pests and diseases, except for larval attacks by *Heortia vitessoides*. Hemiptera group insects like scales and lepidopteran insects like borers and pink disease incidences occur on major parts of the tree and occasionally root wilt issues have been reported (Qiao *et al.*, 2012). Wherever necessary, the application of fungicides like Bourdeaux mixture and Mancozeb, and systemic pesticides like Furadan G should be applied for the protection of the crop.

Major products of Agarwood

The extraordinarily high value of Agarwood products is the real attraction in international markets. However, the quality of Agar greatly influences its price, which can be assessed by an experienced person from the country's old customs. Because of the complicated exterior of marketed Agarwood and individual interests, a standardized quality grading system is unlikely to be accessible. They carried out an in-depth evaluation of the presently followed quality check method in the trade.

Agarwood metabolite analysis has recently attracted more attention since research has revealed a link between the Agarwood quality, resin yield, and metabolite components. To gain a better understanding of Agarwood's biochemical composition produced naturally or through artificial induction, numerous investigations have been carried out. It was reported that the combinations of sesquiterpenes and 2-(2-phenylethyl) chromones (PECs) make up the majority of the composition of Agarwood resin. Meanwhile, it was further discovered that sesquiterpenoids constitutes most of the components in Agarwood essential oil. The distinctive flavorsome qualities of Agarwood are formed by the combination of all of these key chemicals and a few low abundance volatile aromatic metabolites (Liu *et al.*, 2017).

The different Agarwood metabolite components vary in number and kind reported in each study depending on their origin, extraction technique, and analysis strategy used. Moreover, Agarwood has been found to contain more than 150 chemicals[5]. The structures of around 40 different types of PECs and 70 sesquiterpenes have been identified in Agarwood. Various researchers have found that some sesquiterpenes, such as Aromadendrene, Agarospirol, Agarofuran, Guaiol and Aristolene, were highly prevalent in the Agarwood. According to reports, several sesquiterpenes are species-specific. For instance, baimuxinal is only found in *A. crassna* and *A. Sinensis*, whereas jinkoh removal and epi-yeudesmol are only present in *A. malaccensis*. It is important to note that the level of aromadendrene was shown to be higher in better-grade agar and it is recommended as a very efficient chemical constituent for the quality of Agarwood (Pasaribu *et al.*, 2015). When burning Agarwood, the PEC derivatives play a significant role in generating the wood's distinctively sweet, fruity and enduring fragrance, along with other key fragrance components. These substances are never found in the hydro distillation extract and are only detectable using special techniques from CO_2 and solvent removal (Yang *et al.*, 2013).

High-grade Agarwood like kanankoh can contain up to 66.47% of 2 (2-phenylethyl) chromone and 2-(2-4-methoxy-phenylethyl) chromone, which is significantly more than the inferior Agarwood containing only 1.5% chromone. There are 17 different kinds of chromone compounds that are unique to Agarwood and could be used as authentication indicators. With a few exceptions, it was discovered that replicable chromones like agarotetrol and isoagarotetrol had a positive connection with the grade of Agarwood purchased in the industry. The diversity of scent qualities of essential oils in numerous species as revealed by local sources indicates a wide range of main chemical types and derivatives in Agarwood. Identification of globally recognized biomarkers of Agarwood grading will be made easier with a greater understanding of Agarwood metabolites.

Uses

Agarwood has been used medicinally for a long time and is still used in Ayurvedic as well as in traditional Asian medicine (Chakrabarty *et al.*, 1994 and Fratkin, 1994). The high-quality Agarwood powder is employed in the creation of pharmacological tinctures as well as for aromatherapy (Van and Phillips, 1999). It is used in conventional East Asian medicine to improve qi-flow, relieve pain, stop vomiting by warming the stomach and treat asthma (Hajar, 2013). Agarwood was combined with coconut oil and used by Malaysians as a home remedy and in cooked syrup to ease the pain of rheumatism and other types of physical pain (Burkill, 1966). Both Agarwood oil and smoke are commonly used as a perfume in the Mideast (Chakrabarty *et al.*, 1994). Although there are several widely available synthetic Agarwood fragrance compounds, they can only generate lower-quality aromas due to the chemical makeup of natural agar oil (Van and Phillips, 1999). In addition to incense, Agarwood fragrances have been employed in shampoos and soaps (Schippmann, 2001). Burning Agarwood incense emits a fragrant aroma that can be used as a general perfume or as a component in religious occasions. It is used for incense and is highly psychotropic (Qi *et al.*, 2005). Taiwanese people buy Agarwood to make scented sticks that are utilized in religious rituals to bring luck and safety during many traditional festivals and events (Traffic, 2000). It is used for anointing the dead in Japan and is regarded by many as sacred.

Agar yield and economic returns

Aquilaria malaccensis commonly known as "Wood of Gods" is a multipurpose tree species (MPTs) which is mainly used for pharmaceutical and ethnomedicinal purposes. The high demand for Agarwood led to the over-exploitation of the species, which results in the high pressure on its natural population. Due to over-exploitation, the species was listed in IUCN and was categorized as critically endangered and vulnerable. The promotion of afforestation models of species and the development of appropriate Agarwood based agroforestry practices are urgently required to fulfil the demand of industry and prevent over-exploitation of species which will aid in conserving the endangered Agarwood species in natural forests.

It has been estimated that one hectare of plantation sole can generate about Rs 1.5 to 2 crores from oil, besides farmers can also get additional income from the intercrops grown in the interspaces. The Agarwood and tea crop-based agroforestry models can contribute a substantial subsidiary income of up to 45% of the total annual income of the family; indicating the enormous potential of agarwood-based agroforestry practices in improving the livelihood and economy of rural communities. Furthermore, practicing tree management (pollarding, pruning, and coppicing) in agar trees can make it an ideal tree species for agroforestry systems and models. Moreover, agarwood trees as a component in agroforestry systems had been recommended by many researchers in India. Therefore, agarwood-based agroforestry practices can be a viable option both economically and ecologically for the growers in terms of improving their livelihood.

First-grade Agarwood is incredibly valuable and marketed, which varies based on geographic region and cultural deposition and comes with by-products like woodchips, wood pieces, powder, dust, oil, incense materials and scent (LaFrankie, 1994; Barden *et al.*, 2000; Gunn *et al.*, 2004 and Compton and Ishihara, 2004). First-grade Agarwood is among the costliest raw materials available on the marketplace. Similar overprices are offered for its oil. Agarwood essential oil is made from its chips and is marketed for a very high price (Jayachandran *et al.*, 2014). The internal rate of return (IRR) and benefit-cost ratio (B/C ratio) for establishing a 1,000 tree/ha plantation for the production of Bananas and Agarwood, respectively, is 54.85% and >1(3.30) (Mamat *et al.*, 2010). The price of Agarwood chips varies, based on the amount of resin contained in the chips. The basic price can range from US dollars 30 to 9000 per kg (Babatunde, 2015).

CONCLUSION

Agarwood is a highly prized product and is known as black diamond in the South East Asia. Agarwood is extensively cultivated in India due to the greater demand for its products in the international market. Moreover, after the development of the artificial induction technique in Agarwood, many countries have developed large scale plantations of the species. Agarwood trees can make immense contribution in enhancing farm income and generating employment opportunity for the local people. Therefore, the promotion of afforestation models of the species and the development of appropriate Agarwood based agroforestry practices, are urgently required to fulfill the demand of industry and prevent over-exploitation of species in the natural forests.

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