Growing *Aquilaria* and Production of Agarwood in Hill Agro-ecosystems

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Abstract

Aquilaria and *Gyrinops* are genera of tropical trees that produces a valuable resinous wood called agarwood. The aromatic properties of agarwood when burned or distilled are extraordinary and there is high demand for the resinous wood to make incense, perfume and as traditional medicine. *Aquilaria* are native to the State of Mizoram and other regions of northern India but over harvesting of this tree as well as other forest trees in the past has ravaged the hill country. With new technology that has been developed to induce agarwood in trees, it is now possible to produce a sustainable high valued agarwood in young plantation trees. The growing of *Aquilaria* in the hill agro-ecosystems of northern India and cultivation of agarwood as a crop using new technology could provide a new economy for the region.

Historical information on *Aquilaria* and agarwood

Agarwood is a resin filled wood produced in *Aquilaria* and *Gyrinops* trees with a long history of use as incense, perfume and in traditional medicine. Agarwood, has many different names depending on the region of the world where it is found including agar, aloeswood, eagle wood, jinkoh, oud, gaharu, Ch'en Hsiang and Chen-Xiang (Antonopoulou et al. 2010, CITES 2005, Compton and Ishihara 2004). The unusual aromatic properties of this resin were discovered long ago and its unique fragrance continues to be very desirable. The occurrence of the resin within trees is exceedingly rare, and demand has always been far greater than the quantity available resulting in agarwood having extremely high value. It is often referred to as "black gold" and high quality agarwood has equaled or exceeded the price of gold in the past (Barden et al. 2000). Both *Aquilaria* and *Gyrinops* are is not an important timber species and the wood produced is light and not decay resistant. The bark of the tree has been used in the past to make paper and twine and the wood sometimes reported to be used to make boxes or other small items. However, the value of this tree is not in it use of wood for timber but only for the resinous wood that is produced inside some mature trees. This resinous wood, however, is only produced under very special circumstances and its occurrence in trees is very rare (Gibson 1977). In *Aquilaria* trees growing in old growth forests, only one in 100 to 200 trees may have the resin. What induces agarwood to form in some living trees but not others has been an unsolved mystery for millennia.

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Aquilaria and *Gyrinops* are a tropical hardwood trees in the family Thymelaeaceae that once grew in the forests from Northern India and throughout much of the Indomalaya Ecozone (Figure 1). The tree usually is found very sparsely in the forest with just a few trees per hectare. There are many different species of *Aquilaria* and *Gyrinops* that grow throughout Asia but the predominant species in India has been called *Aquilaria agallocha* and is now classified as *Aquilaria malaccensis* (Chakrabarty et al.1994). Another species, *A. khasiana* has also been reported from India but very little information is available on the distribution of this species. Since *Gyrinops* does not occur in northern India, this review will focus on *Aquilaria*. Old growth trees are rare and may only be found in protected forest reserves, national parks or deep within untouched natural forests (Figure 1). The indiscriminate harvesting of this tree that has taken place over the past two thousand years has reduced its population dramatically and seriously threatens the biodiversity of this genus.

Figure 1. Old growth *Aquilaria* tree. Few old growth trees remain today in natural forests due to widespread overharvesting that occurred over the past centuries to find the valuable agarwood resin.

Since agarwood forms very rarely in trees and there is usually little to no external indication that a tree has agarwood in it, all *Aquilaria* are cut by agarwood prospectors in hopes of finding a tree with the resinous wood inside. Indiscriminate harvesting has left most forest landscapes in India and other countries in Indomalaya without *Aquilaria* growing in the wild. The loss of this tree from the landscape has been of great concern and several *Aquilaria* species have been considered endangered according to the International Union for the Conservation of Nature which lists it on their Red List of Threatened Species (IUCN 2013). The Convention on International Trade in Endangered Species of Wild Fauna and Flora has listed *Aquilaria malaccensis* in Appendix II and more recently all species of *Aquilaria* were included so that world wide trade in agarwood is monitored and controlled (CITES 2004). Most old growth trees were

harvested in India many decades ago but some countries like Cambodia, Laos, Indonesia and Papua New Guinea still have trees left in natural forests. Despite protective measures implemented by CITES regulations, *Aquilaria* continues to be cut and exploited in these countries and agarwood is often traded illegally. Historically, *Aquilaria* has been reported to grow in abundance in Mizoram but these trees have been ravaged by prospectors in past years leaving the hillocks stripped of *Aquilaria* (Chakrabarty et al. 1994). This region along with the states of Assam and Arunachal Pradesh in India as well as northern Bangladesh, have ideal growing conditions for *Aquilaria* and it is an area that produced agarwood of extraordinary quality in the past. Projects to locate local seed bearing trees, create nurseries and establish a new agroforestry crop in the hill country could regenerate this economically important tree which would be of great value to local communities. This would provide a sustainable yield of valuable agarwood, a new economy for rural people and reduce the exploitation of *Aquilaria* in natural forests since there is no need to cut old growth trees to obtain the agarwood resin.

Figure 2. Agarwood is a resinous wood formed within living *Aquilaria* trees. This resin has magnificent aromatic properties and has been used for thousands of years to make incense, agarwood oil and traditional medicines.

Uses for agarwood and its value

Agarwood is used throughout the world but there are two major regions of consumption, the Middle East and Asian markets (Antonopoulou et al. 2010, CITES 2005, Compton and Ishihara 2004). Agarwood is most well-known for its fragrance and use as incense and for perfume. The resin filled wood is harvested from trees by extracting it from the surrounding white, unaffected wood (Figure 2). The agarwood chips produced are used directly as high quality incense or may be blended with other aromatic resins or plants to make incense. The aroma of agarwood is considered to be exceedingly special and one of the most sought after and expensive of all incense. High quality agarwood chips are commonly sold for approximately $4,000 USD per kilo but much higher values of

$10,000 USD or more per kilo are often found on the market. The fragrance of agarwood has a pleasant aroma but it also has important aromatherapy and medicinal qualities. It is well known for its use in ceremonies of many different religions. It is burned in temples and used by Buddhists monks during meditation and prayer to achieve a deep inner peace and higher level of consciousness. It is used in mosques and burned to honor guests as well as burned in preparation for prayer (Antonopoulou et al. 2010). The aroma has been reported to have a calming effect and thought to help people focus their attention and improve mental aptitude.

An essential oil distilled from agarwood has a very long history of use as perfume. Known in the Middle East as oudh (or oud) it can be used as a pure oil or blended with various other substances. This essential oil is mentioned in the bible several times as "aloes" wood (Musselman 2007). There are also descriptions of it use in ancient Islamic religious documents and in reports of its extensive use as perfume as early as the 13th century (Antonopoulou et al. 2010, Hansen 2000). A huge demand continues for agarwood oil in the modern world and the whole sale price of high quality oil can be as much as $20,000 USD to $50,000 per liter.

Agarwood has also been used in traditional medicines. It has been reported as a component of many traditional Ayurvedic remedies in the Indian subcontinent as well as being used in Tibetan, Chinese, Malayan and Vietnamese medicine (Antonopoulou et al. 2010, Barden et al. 2000, Kiet 2003, Lim and Anack 2010). More modern studies confirm that agarwood has bioactive products that function as effective anti-microbial compounds, it may have anticancer activity, can be used as an antidepressant and used to promote good health in general (CITES 2005, Dash et al. 2008, Mei et al. 2008, Miller and Miller 1995). The current lack of agarwood supplies and exceedingly high price has affected its availability for use in traditional medicine as well as in modern natural product pharmaceuticals.

Agarwood carvings made into various sculptures and religious objects such as prayer beads are also in high demand. Agarwood is considered to have such important esteem many people display larger pieces of the wood as a symbol of prestige and object of great beauty. Agarwood beads are especially sought after since they release agarwood aroma as the prayer beads are rubbed with the fingers and body heat generates some fragrance. With Buddhists, Muslims, and Hindus using these various carvings, they have become an economically important product produced from agarwood.

Growing *Aquilaria*

The first step to increase supplies of agarwood is to increase the availability of *Aquilaria* trees. Since most of the *Aquilaria* growing in Mizoram have been cut, identification of seed bearing trees that still exist in the region is essential. Once found, propagation must take place when seed is mature. This must be done very soon after the fruit has opened and the seed exposed since seed of *Aquilaria* have a short time period for viability. 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

Figure 3. Seedlings of *Aquilaria*. Propagation of *Aquilaria* can be difficult since seed has a short period of viability and must be planted immediately after it is collected.

Figure 4. Young plantation of *Aquilaria* trees growing in the hill country of Southwestern Vietnam. Trees can be induced to produce agarwood after 5 to 6 years of age.

modern nursery practices, *Aquilaria* seedlings can be produced in large numbers (Figure 3). An excellent example has been provided in a recent European Union Project led by The Rainforest Project Foundation where hundreds of thousands of seedlings were grown from a diverse group of locally preserved *Aquilaria* trees and provided to farmers in Southern Vietnam. These trees were planted in plantations and home gardens and have grown to replenish the hill forests and home wood lots of the region (Figure 4). *Aquilaria* can grow on marginal land and under a wide range of conditions. They are fast growing trees and in areas with adequate moisture, can achieve 10 cm DBH in 4 to 6 years. 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. *Aquilaria* can also be intercropped with other trees (Figure 5). In Southeast Asia, *Aquilaria* has been grown with rubber, teak, banana and even oil palm.

Figure 5. Intercropping of *Aquilaria* with banana. Intercropping can provide needed shade for the young *Aquilaria* until they become established.

Cultivation of Agarwood

The natural production of agarwood takes many decades to develop, and as mentioned previously, when it does form it is usually found in a very small percentage of trees. Over the past years, many techniques have been tried to induce agarwood (Ng et al. 1997). A traditional way used by some farmers is to cause repeated wounding of trees. This method may produce a very small amount of low quality agarwood at times or may be unsuccessful. Another method used in Bangladesh is to apply nails into the tree often with hundreds or even thousands of nails put into each tree (Figure 6). This process is extremely labor intensive and takes a great deal of time to carryout. After many years, each nail wound produces a slight amount of low quality resinous wood and if all of the resin around these nail wounds is collected, the amount can be used for oil extraction.

Figure 6. An unusual treatment to produce agarwood has been to use nails in living trees. This method is labor intensive and not always reliable since it produces small amounts of low quality resin infrequently.

A long term investigation of how *Aquilaria* produces resin in natural forests by the author, colleagues at the University of Minnesota and the Rainforest Project Foundation has provided valuable information on the biological processes involved and the management systems needed for high quality resin production. Field trials over many years using methods that mimic the natural production of agarwood have shown great success and are now being used to produce high quality agarwood in young plantation grown trees in many areas of the Indomalaya region (Blanchette and van Beek 2005). In addition, the production of agarwood is not limited or restricted to just a few trees but can be formed in all trees that are treated. The whole tree can produce resin and it can be found from the base of the tree up into the small branches using this new agarwood inducement technology. Since the methods used and treatments applied require significant expertise to carryout, kits have been developed that can be applied by professionally trained people Figure 7). Proper management of the trees is also required as the resinous wood is formed in the tree. Although the procedures may be difficult for individual farmers to apply, cooperatives or agroforestry industry with trained staff can facilitate the application of the technology and carry out the work easily. This 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.

Figure 7. 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.

The process of agarwood formation involves the synthesis of resin by specialized cells in the xylem of *Aquilaria* (Figure 8). The resin is chemically complex and consists of sesquiterpenes, chromones, fatty acids and phenolic compounds (Naef 2011, Mei et al. 2010). As many as 70 terpenoids have been identified and more continue to be characterized (Espinoza et al. 2014). A few of these compounds include agarofurans, cadinanes, valencanes, guaiances, prezizanes and others. Since the resin is a mixture of hundreds of various volatile and semi-volatile substances along with many other compounds, it is impossible to make a synthetic form of agarwood that has the true

Figure 8. Scanning electron micrograph showing a transverse section of *Aquilaria* wood and agarwood resin. The resinous compounds are produced in specialized cells within the tree. Treatments have been developed to induce the cells to produce copious amounts of resin.

Figure 9. A cross section of a young plantation grown *Aquilaria* tree showing the dark zones of agarwood inside the tree produced after treatment.

fragrance of the pure resinous wood. However, investigations to produce cultivated agarwood have shown that high quality agarwood resin can be produced in trees (Figure 9) and the resin has a chemical profile that is similar to the agarwood produced in natural old growth forests (Espinoza et al. 2014) As would be expected with similar chemistry and chemical signatures, the aroma produced by cultivated agarwood can be indistinguishable from the wild agarwood if wood with similar amounts of resin are compared (Figure 10). Since cultivated agarwood has all the fine qualities of naturally grown agarwood, it provides a sustainable yield of the resin for use in incense, essential oil production, traditional medicine and other cultural uses.

Figure 10. High quality cultivated agarwood chips with high resin content extracted from young *Aquilaria trees*. Cultivated agarwood provides sustainable production and an excellent new crop for the hill agro-ecosystems of Northern India and other regions (Photo courtesy of ScentedMountain.com).

Conclusions

The worldwide demand for agarwood for use in incense, carved ornaments, perfumes and traditional medicine has continued to increase in recent years. The natural existing agarwood from old growth forests has been almost completely depleted and few old growth *Aquilaria* trees exist except in protected forest reserves or deep within natural forests that remain in Indonesia and Papua New Guinea. The loss of *Aquilaria* from the forest is of great concern and efforts are needed to save the existing genetic diversity that remains. Historically, *Aquilaria* was native to Mazoram and other regions of northern India, Bangladesh and Myanmar and the agarwood from this region had an exceptional aroma. New information indicates that *Aquilaria* can be propagated, grown in plantations of home gardens and after the tree reaches approximately 10 cm DBH it can be induced to produce agarwood. New methods designed to mimic the natural processes involved with agarwood formation can be used to treat trees and within two years, cultivated agarwood can be obtained. The cultivated agarwood has the aroma and chemical signature that is similar to naturally grown agarwood. If properly treated and managed, the agarwood is produced throughout the tree and in every tree that is treated. For an agarwood program to be successful, it is necessary to establish a project that can help set up nurseries to propagate *Aquilaria*, train teams of workers that can apply the treatments needed to induce agarwood resin, facilitate the processing of the agarwood and produce end products with high value that can be sold. 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. This high valued crop would benefit rural people and contribute greatly to the economy of the region.

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