Chapter 6
Gyrinops walla: The Recently Discovered Agarwood-Producing Species in Sri Lanka

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Abstract This chapter describes the morphology, distribution, wood anatomy, and variations of agarwood resin contents and resin content of *Gyrinops walla* endemic to Sri Lanka. We revealed for the first time, this species, which populates the lower elevations of the wet zone of Sri Lanka in 2012. More importantly, the recently identified species possesses agarwood-producing ability, similar to other species in the Thymelaeaceae family. Before this scientific discovery, *G. walla* was considered a least valuable species due to the very low stem density. Not much is known about this forgotten species; we intend to unleash its full potential as a new economic commodity to this country.

6.1 Introduction

Gyrinops walla is a tree endemic to Sri Lanka. Due to the minimal timber value and very low stem density, the villagers used to remove this tree from their homesteads; therefore it could only be observed in forests and along live fences. However, in 2012, this species became one of the most commonly discussed topics due to its ability to produce agarwood and the high selling prices associated with it published in the media. During that time, many smuggling efforts were caught by the authorities. Parallel to these activities, we conducted research on *G. walla*'s resin-producing ability (Subasinghe et al. 2012; Subasinghe and Hettiarachchi 2013). As far as our knowledge goes, these were inaugural reports on the species ability to form agarwood. Earlier scientific publications on *G. walla* describe its geographical distribution (Hou 1960) and chemical constituents in the leaves (Schun et al. 1986), which are different from that of agarwood.

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Furthermore, we proved the resins produced in *G. walla* are chemically similar to that of the commercially agarwood-producing species growing in Southeast Asia. Chemical analysis revealed the presence of several sesquiterpene compounds like agarofuran, vetispirane/agarospirol, prezizane, guaiane, eremophilane, and eudesmane/selinane (Subasinghe and Hettiarachchi 2013). We also conducted a study on seed germination, which saw a rapid decline in germination ability after the seeds fell to the ground. In addition, we are currently conducting agarwood resin formation studies using different fungal species following conventional treatment methods such as those adopted by Southeast Asian countries on *Aquilaria* species. In this chapter, we review the present scientific knowledge on *G. walla* including its distribution in Sri Lanka, wood anatomy, and chemical constituents and discuss issues related to its conservation and future prospects in Sri Lanka.

6.2 Botanical Description and Distribution

Gyrinops walla grows as a small to medium size tree (Gunatilleke et al. 2014) generally up to 15 m with a straight, slender but erect stem and a small rounded crown (Fig. 6.1a) (Dassanayake and Fosberg 1981). However, the crown shape can change from elongated to umbel depending on the position of the tree in the forest canopy and its growing stage. This tree bears numerous amounts of branches with slender and wiry twigs. The bark is smooth, thin, and strongly fibrous and its color varies from gray or brownish gray to reddish brown. *Gyrinops walla* leaves are alternatively arranged, slightly shinning and simple, and the buds are silky. Leaf shape is oblong and acute at the base. The average mature leaf size is 3.5 × 10 cm with a short rather abrupt bluntish acumen up to 1 cm long. Lateral veins of this species are very fine and numerous in number. The midrib is prominent. The petiole is short and 1–6 mm in length.

This tree bears bisexual flowers in the inflorescence. The flowers are small, slender, pubescent, and yellowish. Each flower bears 3–5 pedicels in shortly stalked umbels of axils. They contain tubular and slender perianth, which contains a ring of short hairs and scales above stamens. The ovary is superior with a pendulous ovule in each loculus. The fruit of *G. walla* is about 1.8 cm long capsule and obvate in shape and reddish brown, which bears two tadpole-like seeds in two valves. These seeds (Fig. 6.1b) are acuminate at the tip and covered with brown hairs and pointed (Dassanayake and Fosberg 1981; Jayaweera 1982).

Gyrinops walla is distributed in damper areas in the lower elevations of Sri Lanka, mainly in the humid lowland forests and home gardens of the southwest region (Fig. 6.1c). The elevation of this region is lower than 1000 m and the annual rainfall is between 2000 and 3000 mm. The average temperature is 25–27 °C. *Gyrinops walla* is also found in the moist forests of the central province of Sri Lanka where the elevation is higher than 1000 m, and the annual rainfall is lower than that of the southwest part of the country. However, we found that it is possible to observe this species in other climates (Subasinghe 2015).

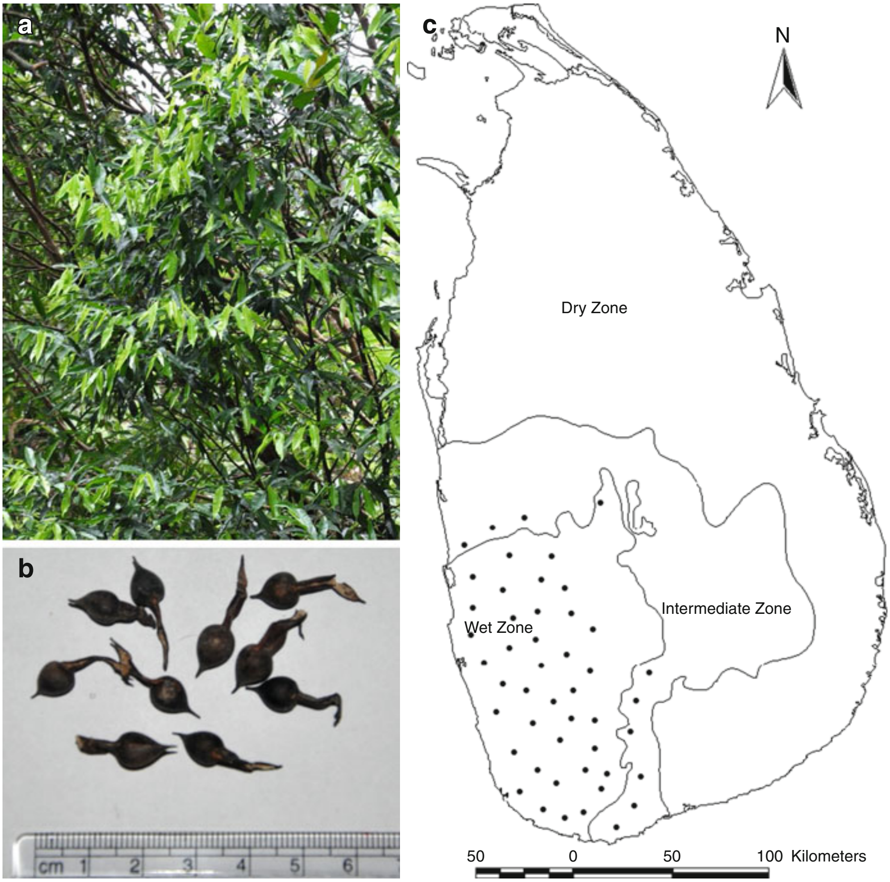

Fig. 6.1 Botanical features and distribution of *Gyrinops walla*. (**a**) Tree canopy, (**b**) seeds, and (**c**) distribution map in Sri Lanka

6.3 Traditional Use of the Tree

The fibrous bark of *G. walla* is well known for its durability. It can be easily stripped from the stem as narrow and long bands. Due to the strength of the bark, local people had used the bark strips to bind things like traditional medicinal pastes on broken limbs of human and large mammals such as buffaloes to help the healing process. Villagers also used the tender leaves of *G. walla* as vermifuges, especially for young children in those days when Western medicines were not popular for such purposes. Leaves were applied as poultice on boils and fistula, and in snake bites, often leading to recovery. Macerated leaves were also placed in the tooth cavities to loosen the infected teeth for easy removal. The tree has also been used for preparation of medicinal oils (Jayaweera 1982). The wood of *G. walla* is white or yellowish and very soft in nature. The stem wood density is 345 kg m^{-3} (Welivita and

Subasinghe 2006); therefore it has little value. The villagers used its wood for making handles for their gardening tools, but it has never been utilized for construction, furniture manufacturing, or similar uses in Sri Lanka.

6.4 Wood Anatomy

In our attempt to determine the species identity, we captured important elements of its wood anatomy under the microscope. Microscopic images of transverse, radial, and tangential sections of the tree stem are shown in Fig. 6.2a–c (unpublished data of the State Timber Corporation, Sri Lanka), respectively. *Gyrinops walla* has undefined growth rings in the stem (Fig. 6.2a). These growth rings are not clearly visible in the stem cross sections under the naked eye or even under the microscope. The main reason could be that this species is growing under favorable conditions throughout the year. The hallmark of trees from the Thymelaeaceae family including *Gyrinops* are the included phloems (Mohamed et al. 2013; Jiao et al. 2014), which are visible in the transverse section (Fig. 6.2a). The xylem vessels are mostly

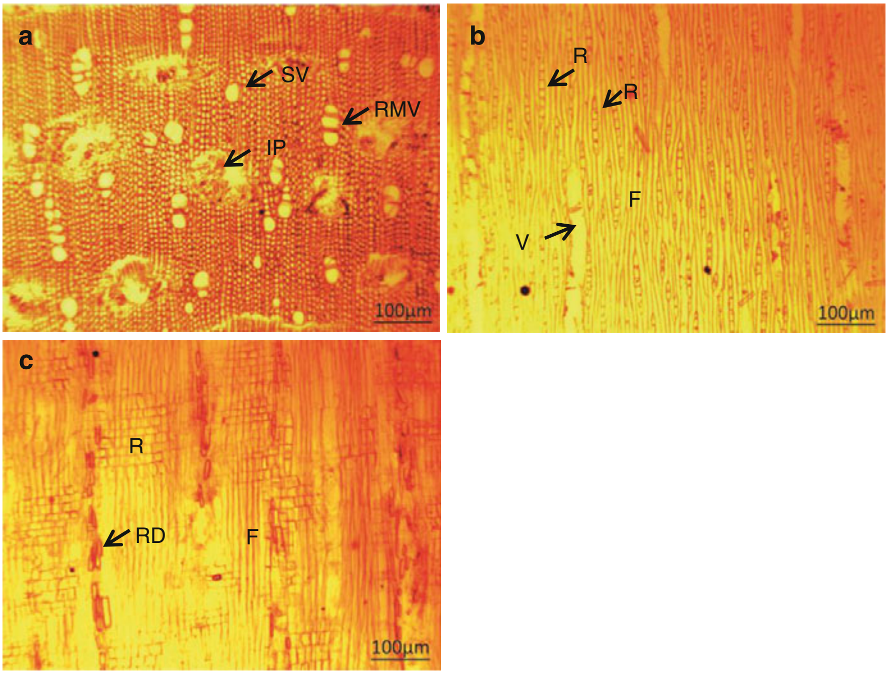

Fig. 6.2 Anatomical features of *Gyrinops walla*. (**a**) Transverse, (**b**) radial, and (**c**) tangential sections. Scale bars, 100 µm. *IP* included phloem, *SV* solitary vessel, *RMV* radial multiple vessel, *R* ray parenchyma, *F* fiber, *V* vessel, *RD* resin deposit (Source: State Timber Corporation of Sri Lanka)

radial and multiple, but a few solitary vessels are also present. The vacant areas, which are larger than the vessels, could be observed as the resin canals. The ray parenchymas are clearly visible in the tangential (Fig. 6.2b) and radial (Fig. 6.2c) sections. These living cells are possibly responsible in agarwood formation.

6.5 Chemical Constituents

In order to identify its quality, the agarwood produced in *G. walla* was heated on a hot piece of charcoal and a sensory panel assessed the odor. The top note was recorded as of sweet fruity aroma, followed by a short bodily middle note, and a lasting oriental woody base note. These odor notes were similar to what have been reported on agarwood of *Aquilaria* origins (Naef 2011); thus the use of *G. walla* as an agarwood source is confirmed.

Chemical constituents of *G. walla* have been reported by Schun and Cordell (1985) for its leaf constituents and their potential anticancer activity. Of the numerous compounds they extracted, two showed considerable activity against cancer cells. Furthermore, a triterpenoid named wallenone has been isolated and characterized from the leaves (Schun et al. 1986). The leaf, bark, and uninfected stem tissues were also studied using thin layer and gas chromatographic analysis (Dharmadasa et al. 2013). However, the current authors (Subasinghe et al. 2012; Subasinghe and Hettiarachchi 2013) were the first to characterize agarwood from *G. walla* and its chemical constituents. The initial attempt was to identify fragrant molecules previously reported in other agarwood-producing species such as from *Aquilaria* origin: *A. malaccensis* (synonym *A. agallocha*), *A. crassna*, and *A. sinensis*. Essential oil from agarwood contains sesquiterpene compounds and 2-(2-phenylethyl)-chromone derivatives and in some cases includes fatty acids (Naef 2011; Chen et al. 2012).

During the past 4 years, we studied over 150 individual *G. walla* trees containing agarwood. These trees were growing in various climatic regions of Sri Lanka. Chemical analysis of the above samples revealed that resins produced in *G. walla* have some major compound classes. However, the distribution and quantity varied between samples. This is not surprising because it is now known that agarwood formation depends upon several internal and external factors that affect the tree, including the type and time of attack. Those factors, however, do not affect the availability of major compound classes (Xu et al. 2013). Chen et al. (2012) have reported six different classes of sesquiterpenes from agarwood, while Naef (2011) has made a more elaborative classification of eight classes.

Our studies have identified six classes of sesquiterpenes from *G. walla* (Table 6.1). Agarofuran, agarospirol, and jinkohol types have been reported by several groups (Maheshwari et al. 1963; Varma et al. 1965; Nakanishi et al. 1981), while eudesmanes and guaiane types have been reported in a series of studies conducted by Ishihara et al. (1991a, b, 1993a, b); all were described from *Aquilaria* species. Apart from the sesquiterpenes, 4-phenyl-2-butanone has been identified as a major

Table 6.1 Sesquiterpene molecules identified in *Gyrinops walla* via GC-MS

Sesquiterpene class	Compound
Agarofuran type	Agarofuran
Vetispirane type/agarospirane type	Agarospirol
Vetispirane type/agarospirane type	Baimuxinic acid
Vetispirane type/agarospirane type	*oxo*-Agarospirol
Vetispirane type/agarospirane type	*Unknown compound*[a]
Vetispirane type/agarospirane type	*Unknown compound*[a]
Vetispirane type/agarospirane type	*Unknown compound*[a]
Prezizane type	Jinkohol
Prezizane type	Jinkoh-eremol
Guaiane type	Azulenone
Guaiane type	*Unknown compound*[a]
Guaiane type	Aromadendrene
Guaiane type	Isolongifolene
Guaiane type	Alloaromadendrene oxide
Guaiane type	Guaia-(10),11-dien-15-ol
Guaiane type	*Unknown compound*[a]
Eremophilane type	9,1-Eremophiladien-8-one
Eremophilane type	Isopropyl naphthalene (derivative)[a]
Eremophilane type	Isopropyl naphthalene (derivative)[a]
Eudesmane/selinane type	γ-Eudesmol
Eudesmane/selinane type	Valerenol
Eudesmane/selinane type	γ-Elemene
Eudesmane/selinane type	2,2,6,8-Tetramethyl bicyclo undece-7-en-3-ol
Eudesmane/selinane type	β-Selinene
Eudesmane/selinane type	Eudesmane-4-(14), 11-diene
Eudesmane/selinane type	Selina-3,11-diene-9-one
Eudesmane/selinane type	Selina-3,11-diene-14-al

[a]Mass spectroscopic and Kovat's indices matched to the sesquiterpene class but could not be configured to a particular compound

aromatic compound, which is present in every agarwood sample analyzed during our studies; these aromatic ketones have been reported from agarwood of *Aquilaria* origin (Chen et al. 2012). Upon analysis of the dichloromethane extract, we identified two 2-(2-phenylethyl) – chromones. Further investigations into chromone compounds are necessary as they have been identified as potential markers for identifying agarwood origins (Espinoza et al. 2014) and thus could be applied to *G. walla*.

In our research, the retention indices (RIs) of *G. walla* constituents were compared to that of authentic *A. crassna* (Wetwitayaklung et al. 2009), *A. sinensis* (Chen et al. 2012), and *A. agallocha* (Nor Azah et al. 2008) (Table 6.2) (Subasinghe and Hettiarachchi 2013). The results confirmed the similarity of agarwood resins produced in *G. walla* with that of the tested *Aquilaria* species.

Table 6.2 Retention indices (RIs) of several compounds identified in *Gyrinops walla* compared to *Aquilaria* species using a 5 % phenyl and 95 % methyl siloxane capillary column (DB-5 type)

Compound	*G. walla*	*A. crassna*	*A. sinensis*	*A. agallocha*
Jinkoh-eremol	1641	1643	–	1650
Selina-3,11-diene-9-one	1689	1687	–	–
Selina-3,11-diene-14-al	1733	1735	1733	–
9,11-Eremophiladien-8-one	1741	1740	–	–
Guaia-(10),11-dien-15-ol	1766	1770	–	–
oxo-Agarospirol	1818	1822	–	–

Source: Subasinghe and Hettiarachchi (2013)

6.6 Conservation Status

6.6.1 Illegal Harvesting

Due to the facts that products from naturally formed agarwood enjoy high prices in the world market and supply of such agarwood from Southeast Asian countries is decreasing, agarwood from the virgin *G. walla* resources in Sri Lanka has drawn a great deal of attention from high-end users and traders. To make matters worse, the lucrative financial figures published in the media also attracted illegal harvesters, which significantly enhanced the extent of poaching. Illegal harvesting activity reached its highest peak within the last 2 years. Poachers cut the trees without having prior knowledge on the availability of agarwood within the stems. This act had sacrificed a large number of trees in the rainforests of the country. Once the tree populations of such forests declined, poachers turned to homestead-grown trees. According to published media information, within 2013, the police and customs of Sri Lanka had confiscated 13,800 kg of processed agarwood chips. However, the real figure could be much higher because essential oils extracted from the chips have not been seized.

6.6.2 Present Legal Status

The numbers of *G. walla* quickly dwindled in Sri Lanka after 2012. Apparently, the high monetary value of *G. walla* made publicly by both electronic and printed media had attracted illegal harvesters who poached agarwood. In addition, villagers also cut *G. walla* trees in search of agarwood resin inside the stems. Because of lack of knowledge about agarwood formation and its subsistence, people cut trees of all sizes causing a severe threat on the existence of this species. Consequently, the authorities captured many smugglers, both local and foreign. In December 2012, the Biodiversity Secretariat of Sri Lanka recategorized *G. walla* as "vulnerable" species, after which the export of timber, tissues, or any extracts from the species was banned.

6.7 Germination and Propagation

There was very little research focusing on *G. walla*. Furthermore, cultivation and plantation were not established in the past because the species had not been recognized as having any commercial value. Propagation of this species was made in the traditional way, and no attempts were made on seed germination until we conducted the first trial under funding from the National Research Council of Sri Lanka in 2013. We found that the germination rate increased up to 55 % when seeds were sown in pure coarse sand with good draining. To maximize germination success, the seeds must be germinated within the first 2 weeks after dropping from the trees because their viability declines rapidly. The use of different seed treatments may enhance the germination rate. One difficulty faced by researchers is the low availability of *G. walla* trees due to the heavy poaching. In addition, the small-sized green fruits are well camouflaged in the tree canopies, resulting in difficult fruit harvesting. The ripened fruits attract birds such as the hornbills, which feed on them.

6.8 Agarwood Production Ability of *G. walla*

We tested agarwood-producing ability of *G. walla* in trees growing under natural conditions and in three different populations, i.e., Ingiriya, Mirigama, and Yagirala, all in the low country wet zone of Sri Lanka. The wet zone seems to favor *G. walla*'s growth and the abundance was high at the time our research started. To increase the distance between the three populations, the areas for sample collection were selected from three different administrative districts within the Western Province. Diameters of the selected trees varied from 8 to 21 cm and the heights varied from 10 to 24.5 m.

Careful observations were made in identifying stems or branches that contain naturally formed agarwood. Once located, such resinous wood was manually separated from the healthy wood, and the particle size was manually reduced before extracting with dichloromethane using the cold maceration method. Chemical analysis was conducted using gas chromatography–mass spectrometry (GC-MS) as commonly applied in essential oil analysis. Extracts were dissolved in anhydrous acetone before injected into the instrument. Narrow-bore capillary columns were used with both 5 % phenyl siloxane and polyethylene glycol inner coating attached to a guard column. From our preliminary testings, we found that the 5 % phenyl siloxane column was more efficient at separating different classes of compounds. Separated compounds were identified by comparing the fragmentation patterns of mass spectroscopy and Kovat's indices of published data (Nor Azah et al. 2008; Wetwitayaklung et al. 2009; Chen et al. 2012).

The resin contents varied from 0.68 to 3.8 % for the three populations, with averages between 1.8 and 2.4 % (Fig. 6.3); however the values were insignificantly different. The results proved for the first time that *G. walla* produces agarwood

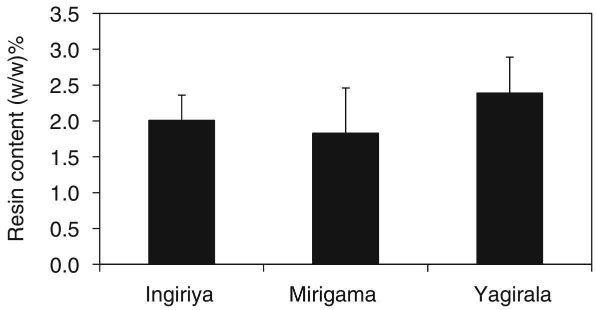

Fig. 6.3 Mean in resin content within the selected *Gyrinops walla* populations (±SE)

resins due to natural reasons. However, destructive sampling was not conducted during this experiment, and therefore the agarwood volume as a percentage to the entire tree volume was not estimated.

The three populations have shown a variation in the distribution of resin constituents. Most of the samples analyzed contained key agarwood aroma compounds such as agarofuran, agarospirol, phenyl butanone, jinkohol, guaiane-type sesquiterpenes, and chromones (Table 6.3). Mirigama sample was rich in sesquiterpenes but phenyl butanone was absent, whereas agarofuran was absent from Ingiriya sample. The most prominent sesquiterpenes were jinkohol, alloaromadendrene oxide, and azulenone, whereas some vetispirane-type sesquiterpenes were found only in a few samples. These variations could occur because of geographic variations among the selected populations, resin age, and other factors that might have played significant roles in resin variations.

During our studies, we have developed a gas chromatographic fingerprint for *G. walla* resin (Fig. 6.4 and Table 6.3), which could be compared between *G. walla* samples and against agarwood of other species. Chemical fingerprint of *G. walla* was compared to that of several authentic agarwood samples obtained from *A. malaccensis* and *A. crassna*. The distribution of major sesquiterpenes responsible for aroma could also be compared based on the fingerprint where peak retention was confirmed by Kovat's indices. In accordance with the results, agarwood produced in *G. walla* has similar quality to commercial agarwood available in the market. Future chemical analysis would elucidate the absolute chemical identities of key compounds in *G. walla*, which could be compared with reports from other species. These marker compounds will be used as a tool for quality assurance of *G. walla* as a more sustainable source of agarwood.

6.9 Current and Future Research

There is very limited information on agarwood production in *G. walla* when compared to its closely related species from *Aquilaria* origin. This is expected because of the recently discovered status of this species in Sri Lanka. Realizing the importance of *G. walla* to the economy of this country, currently we are conducting studies targeting at commercializing *G. walla* through plantation establishment for

Table 6.3 Main compounds and compound types identified in *Gyrinops walla* via GC-MS

No	Compound	Type	Ingiriya	Mirigama	Yagirala
1	4-Phenyl-2-butanone	NA	2.52 ± 0.85	0.00	1.83 ± 0.86
2	Agarofuran	Agarofuran	0.00	3.22 ± 1.21	0.46 ± 0.19
3	Agarospirol	Vetispirane	1.10 ± 0.65	0.59 ± 0.29	0.90 ± 0.33
4	Unknown	Vetispirane	0.00	0.00	1.88 ± 0.90
5	*oxo*-Agarospirols	Vetispirane	1.90 ± 0.72	0.51 ± 0.21	2.40 ± 0.86
6	Unknown	Vetispirane	0.71 ± 0.41	0.00	0.88 ± 0.35
7	Baimuxinic acid	Vetispirane	0.00	1.46 ± 1.03	1.05 ± 0.34
8	Jinkohol	Prezizane	6.5 ± 0.28	13.71 ± 3.60	5.36 ± 1.34
9	Azulenone	Guaiane	3.48 ± 0.60	9.61 ± 3.24	8.48 ± 2.87
10	Aromadendrene	Guaiane	0.00	1.20 ± 0.69	1.06 ± 0.39
11	Isolongifolene	Guaiane	1.00 ± 0.58	3.33 ± 0.53	2.38 ± 0.58
12	Alloaromadendrene oxide	Guaiane	2.96 ± 0.16	14.80 ± 3.99	7.31 ± 1.03
13	9,1-Eremophiladien-8-one	Eremophilane	0.00	3.49 ± 2.04	3.01 ± 1.44
14	Guaia-(10),11-dien-15-ol	Guaiane	0.59 ± 0.34	0.00	1.44 ± 0.55
15	Eudesmane-4-(14), 11-diene	Eudesmane/selinane	1.09 ± 0.69	0.73 ± 0.33	2.45 ± 0.94
16	β-Selinene	Eudesmane/selinane	0.67 ± 0.39	4.8 ± 2.43	0.51 ± 0.22
17	Octadecanoic acid	Fatty acids	1.13 ± 0.72	7.69 ± 2.92	3.63 ± 1.62
18	2-(2-Phenylethyl)-chromone derivative	2-(2-Phenylethyl)-chromone	1.00 ± 0.88	10.88 ± 7.49	3.63 ± 1.83
19	2-(2-Phenylethyl)-chromone derivative	2-(2-Phenylethyl)-chromone	14.99 ± 2.20	4.55 ± 4.24	7.26 ± 2.26

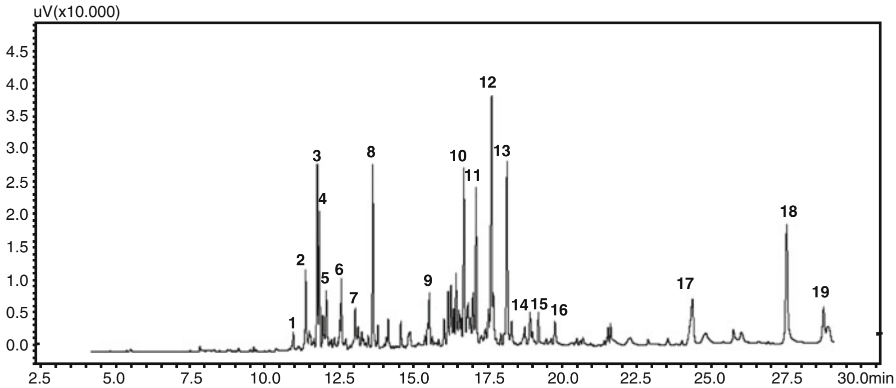

Fig. 6.4 A representative gas chromatographic fingerprint of *Gyrinops walla* extract. *Number* on each peak matches the compound listed in Table 6.3

agarwood cultivation. This research is jointly funded by the government of Sri Lanka and the private sector. The objective is to identify optimal practices in seed germination and nursery handling for improving seed germination rates and survival of *G. walla* seedlings because seedlings are in high demand for starting a plantation.

To cultivate agarwood, different conventional methods are being tested on *G. walla*. In addition, fungal species colonizing naturally formed agarwood tissues and soils where *G. walla* communities are present have already been isolated and identified. They include members of *Trichoderma*, *Fusarium*, *Aspergillus*, and *Diplodadium* from the agarwood tissues, and *Mucor*, *Aspergillus*, *Fusarium*, *Dendrophoma*, *Trichoderma*, and *Absidia* from the forest soils. It is expected that some of these fungal inhabitants of agarwood tissues and forest soils are capable to enhance agarwood formation due to natural reasons. To test their ability, several isolated species have been inoculated into *G. walla*, and the physical and chemical properties of the trees are being measured at present.

Differences in resin content and constituents will be compared between artificially and naturally formed agarwood using standard hydro-distillation method and GC-MS. Our previous testings found that the ionization method used in GC-MS was intense and resulted with similar fragmentation patterns to related compounds. Therefore, absolute identification of derivatives of a certain class of compounds was not possible. In the future, a tandem liquid chromatography with mass spectrometry will be experimented. This method will provide the ability to analyze nonvolatile compounds such as 2-(2-phenylethyl)-chromone derivatives as reported by Lancaster and Espinoza (2012). Other methods such as GC-FTIR and NMR spectroscopic analysis will also be tested in the future. In addition, we are currently developing an optimized thin-layer chromatography (TLC) method for *G. walla*, which has thus far not been reported. The aim of a TLC method is to quantitatively and qualitatively asses the resin with reference to major chemical compound classes. Due to the high monetary value, agarwood resin extraction methods have to be optimized. Three critical parameters, i.e., soaking time, pressure, and distillation durations, will be tested for this purpose.

6.10 Conclusion and Future Perspectives

Our studies proved that the quality of agarwood produced in *G. walla* was similar to that produced by *Aquilaria* species from Southeast Asian regions. *Gyrinops walla* contains all key compounds found in *Aquilaria* species, including 2-(2-phenylethyl) chromones which are unique to agarwood (compounds 18 and 19 in Table 6.3). This places *G. walla* at par with other known agarwood-producing species in the world.

The key activities in agarwood trade are nursery and plantation establishment, agarwood cultivation, resin extraction, and product manufacturing. Unfortunately, *G. walla* plantations are not available in Sri Lanka. Due to the present policy of the government that does not permit oil extraction from *G. walla* for export, and complicated transport issues, plantation establishment is not popular among the villagers or private sectors. In addition, agarwood oil extraction factories or relevant industries have not been established in the country. The present unclear legal status has become a constraint to implement income generation opportunities. Agarwood plantation is considered a short-term business owing to the brief rotation cycle when compared with other forestry-related investments such as teak and mahogany plantations. Because agarwood is a fast income-generating business, the private sectors in Sri Lanka have started introducing *Aquilaria* plantations as short-term forestry projects, which are gaining popularity since the last 2 years. In the future, more large- and medium-scale *Aquilaria* plantations will be established in Sri Lanka rather than the endemic *G. walla* if the legal barriers are not relaxed. It is also not clear if export will be allowed for *G. walla* trees grown in private lands even under the strict supervision of the government officials such as the Forest Department or Department of Wildlife Conservation. Ironically, the government has branded agarwood from *G. walla* as "Sri Lankan agar." Although this is a positive step in creating a new image and foreseeably demands for Sri Lankan agarwood in the international market, proper regulations have to follow, which promote cultivation of agarwood from this species as well as protecting its natural population in the forest. If export of agarwood from *G. walla* is permitted, government intervention is still necessary in creating proper market channels. Extensive research is needed in product manufacturing as to diversify the agarwood industry in Sri Lanka, from supplying raw materials to manufacturing and exporting the end products to rich nations. This would be a more sustainable approach to boost the economy of the people and the country.

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