Frankincense Varieties and Habitats, Part 2

Part one of this two-part series explored frankincense geopolitics, trade and transparency. Part two discusses varieties and habitats.

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***Editor's Note:** This article is part of a two-part series on the world of frankincense. Part one discusses frankincense geopolitics, trade and transparency along the supply chain, which you can read in the September print and digital edition of *Perfumer & Flavorist*.

We thought it would be easy to write this article. We had all lectured on the subject many times, met many of the world's leading frankincense experts, travelled widely in the harvest zones and read literally hundreds of articles, web sites, papers and reports about this product – and yet it has been a struggle to complete. What sticks most in our minds are the huge gaps in our knowledge, the glaring inconsistencies and inaccuracies of available data and the constant nagging question:

Why, despite all the fabled wealth generated by this ancient substance, are the harvesters still some of the poorest people in the world living in some of the most unsafe and inhospitable places on Earth?

One short article will not answer this question, but we want to encourage the reader to think beyond the exotic stories and promotional material that are increasingly published in both the press and academia and begin to search for, invest in and promote solutions that aim to improve the livelihoods and socio-economic status of the people who harvest this ancient commodity.

B. dalzielii ranges across West Africa, from southern Mali as far east as Cameroon. *B.papyrifera* begins in northern Cameroon and ranges east to the Red Sea, with the bulk of the trees found in Ethiopia (the major supplier), Southern Sudan and Eritrea. Ethiopia alone hosts six species of *Boswellia*, including the commercially harvested *B. papyrifera*, *B. rivae* and *B. neglecta*. Kenya contains extensive areas of *B. neglecta* and to a much lesser degree *B. rivae* and *B. papyrifera* on its northern borders. Somalia claims six species, including the endemic *B. frereana*, while the highest known density of *Boswellia* species is found on tiny Socotra Island, which, despite its small size, hosts eight endemic species. *B. sacra* is found in Oman and mainland Yemen. It also grows in Somalia and across the horn of Africa where it is known as *B. carteri*. India hosts an endemic species (*B. ovalifoliolata*), as well as the much more commonly known and harvested *B. serrata*.

The *Boswellia* Habitat

While different species of *Boswellia* trees show marked habitat preferences, most are surprisingly resilient and can grow in a wide range of habitats (see **T-1**). By and large they are found in arid, harsh, resource-scarce environments where few other species survive. In both Oman and Yemen and across the Somali region, *B. sacra* trees are found in arid wadis (dry riverbeds) and on the limestone or volcanic rocks of the seaward-facing mountains. As Salah Ajeeb, Sudanese frankincense expert based in Oman points out in these regions the little researched role of mist and fog in producing good quality frankincense is critical. Here, they usually must rely on the oceanic mists and fogs for water and nutrients. In Somalia, the trees often specialize on growing on sheer rock, storing water in bulbous roots, and are seldom found growing roots in soil. By contrast, *B. frereana* trees prefer even drier lowland conditions on the coastal plain, rarely found in the high-altitude mists that *B. sacra* prefer. In Oman, the grades of resin (Hojari, Shaabi, Najdi, Shazri) actually refer to four different ecological zones with each grade producing recognizably different types of resin from the same *B. sacra* species. Geographers at Sultan Qaboos University in Oman have shown that climate change and deforestation are already having a marked impact on the volume and frequency of mist and fog on the Dhofar coastline. We suspect that this problem is even more serious in the Sanaag Mountain region of coastal Somalia and will become ever more severe in both locations.

Before it became too insecure, researchers in the 1990s from both Sweden and Scotland undertook extensive research on geography of frankincense on Socotra Island. They found that the trees take advantage of these oceanic mists, with specific species tending to inhabit specific zones; four species are found only on cliffs, while the ground-rooted species occupy only specific micro-ranges based on the type of soil. By contrast *B. papyrifera*, one of the most wide-ranging species, is somewhat less particular about its habitat. As professor Frans Bongers of Wageningen University and renowned expert on this species points out although *B. papyrifera* typically prefers rocky slopes and poor, iron-rich soils, it can be found growing across a range of

T-1. Key species in trade

Species	Main source
B. Sacra (syn carterii)	Somalia, Oman, Eritrea
B. Papyfera	Ethiopia, Sudan, S.Sudan, Eritrea
B. Dalzelii	Nigeria, Burkina Faso, Mali
B. Neglecta	Kenya
B. Serrata	India
B. Frereana	Somalia
B. Rivae	Ethiopia, Somalia, Eritrea

altitudes, soil types and rainfalls, from the arid Sahel to the comparatively water-rich dry tropical forests." In areas with high rainfall, *B. papyrifera* trees can be found at extraordinary densities, up to 1,100 trees per hectare" points out professor Bongers. The main known populations are in the Nuba Mountains and Jebel Mara in Sudan, Tigray, Amhara and Benishangul-Gumuz provinces of Ethiopia, and northern Eritrea. Both *B. dalzielii* and *B. serrata* are similarly hardy species, although they prefer to inhabit dry mixed tropical forests in the West African Sahel and Indian interior, respectively. Both species grow to a considerable size in fertile soils, while being able to grow in a range of soil types. Researchers at the Tropical Forest Research Institute at Japalpur in Central India point out that *B. serrata*—unlike most *Boswellia*—is frost-tolerant and serves as a nurse tree for other species. Although the Deccan plateau of Madhya Pradesh and Maharashtra are where most commercial harvesting is undertaken, *B. serrata* can actually be found much farther south in North East Sri Lanka and Karnataka, and as far north as the Indo Pakistan border in Punjab.

The Diversity of Frankincense: Species or Chemotypes?

As Josef Brinkmann, board member of the American Botanical Council points out this confused botany and the seemingly endless changes in the nomenclature of frankincense has not only confused buyers and consumers but also industry formulators and more importantly regulatory experts who draw up quality control standards for frankincense. An urgent review of the differing standards for frankincense in different countries and different industries is required to clarify overlaps and ensure more uniformity.

Moreover, as professor Ahmed Al-Harassi and Nicolas Baldovini, Ph.D., point out in their excellent

The World of Frankincense

Let us start with the basics. Where does frankincense come from? Most of us have seen those ancient Roman maps of Ptolemy and other Greco-Roman geographers which focus on the Red Sea and Arabian Peninsula. Despite the Arabian imagery with which frankincense is often closely associated, Boswellia trees actually grow widely across the globe and there are in fact far more frankincense trees in Africa and the Indian subcontinent than the Arabian Peninsula!

recent article on frankincense chemistry in the August 2019 edition of *Perfumer & Flavorist*, an individual species can have multiple distinct chemo types. As a result, purely botanical DNA based identification of species may not be the most useful way to classify and develop standards for frankincense essential oils. Rather, classification by both species and chemo type may be needed to provide a whole picture of the origin, type and likely aroma of the essential oil produced.

New Discoveries, New Species, New Aromas

Even though traded and used for centuries, in the last 20 years there has been a sudden spate of new discoveries in the field of frankincense; new species have been described, new chemo types discovered, and new sources of unique aromas found. Much of these recent developments have emerged because of improved technologies for identification and analysis as well as novel methods of monitoring resin harvests and transport. These new methods are helping scientists overturn many long-held misconceptions and correct much inaccurate and misleading information about frankincense, its properties and habitat.

In 2001, professor Mats Thulin from Uppsala University published the discovery of two new species *B. disocoridis* and *B. bullata* from the tiny island of Socotra Island off the Red Sea Coast. *B. bullata* produces an unusual mix of sesquiterpenes, while two of the authors of this present article (DeCarlo, A. and Johnson,S., 2019) have very recently published the discovery of the extremely interesting species *B. occulta*, from Somaliland. (This species produces a unique methoxyalkane-dominant aroma unlike that of any other known essential oil.) Recent work by professor Amadé Ouédraogo in Burkina Faso has done much to increase interest in *B. dalzielii*—a previously largely ignored West African *Boswellia* species—which has just been found to possess an alpha-pinene dominant oil that aligns very well with current commercialized species and chemo types.

Given the vast, remote and inhospitable habitat that Boswellia thrives in, we suspect that more species and chemotypes will soon be discovered as interest in the plant grows and survey techniques improve. Furthermore, work on hybridization by scientists like Jason Eslamieh, Ph.D., in California will result in several new types of frankincense emerging with special olfactory and agro-ecological features. Although these new developments are

THE MANY USES OF FRANKINCENSE

- Frankincense incense (prayer, meditation, fumigation)
- essential oil
- hydrosol
- non-volatile components (Boswellic acids)
- water/beverage
- chewing gum
- honey
- soap
- bark (for medicine)
- ice cream and sweetmeats
- perfume balls (bokhuur and uunsi)

A Brief Look at Frankincense Chemistry

The gum resin of the Boswellia. species mainly consists of polysaccharide gum, resinous di- and triterpenic acids, and volatile oil with different proportions of different constituents that vary from species to species.

The volatile oils (essential oils) of the oleo-gum-resins are largely composed of terpenes. Most commonly, the essential oils are dominated by a-pinene or a-thujene, with minor components also prominent such as limonene, myrcene, sabinene, *p*-cymene, terpinen-4-ol, b -caryophyllene or viridiflorol. Researchers at the University of Wageningen, University of Nizwa and APRC in Utah as well as elsewhere have discovered that the gum resins *b.serrata*, *b.papyrifera*, and *b.sacra* (syn carteri) contain different combinations of bioactive pentacyclic triterpenic acids, namely a-Boswellic acids, b-Boswellic acids, g-Boswellic acid, acetyl-b-Boswellic acid, 11-keto-b-Boswellic acid (KBA), acetyl-11-keto-b-Boswellic acid (AKBA), and tetracyclic triterpenic acids like tirucallic acids viz 3-oxotirucallic acid, 3-hydroxytirucallic acid, and 3-acetoxytirucallic acid. Other oleo gum resin compounds which display biological activities are: betulinic acid, lupenoic acid, epi-lupeol, isoincensole, isoincensole acetate and 1-ursene-2-diketone-incensole acetate along with few other terpenes. It should be noted that Boswellic acids are not found in the volatile components.

Even relatively minor differences in the chemical profiles of the essential oils, especially in the heavier sesquiterpenes can yield significantly different aroma profiles—two different *B. sacra* essential oils can smell completely different! At least two *Boswellias* have very different constituents to the *B. sacra*, *B. dalzielii*, *B. serrata*, *B. neglecta* group, namely *B. papyrifera*, which produces essential oils rich in octyl acetate and octanol, and *B. occulta*, which produces methoxyalkanes such as methoxydecane and methoxyoctane.

(For more details see *Perfumer and Flavorist* August 2019)

indeed exciting and interesting one cannot help but note that the vast majority of R&D into new aromas and value-added frankincense products is done in places like USA, Europe and China far from the site of the harvesting and collection.

A survey conducted in 2016 by the late Mohsin Al Aamri, Ph.D., an expert working with the Environmental Society of Oman, clearly indicates that even in a relatively wealthy country like Oman the people who harvest, sort and grade the product get only a tiny fraction (less than 5%) of the total value added to frankincense by manufacturers, distributors and retailers (see **T-2**).

Trade Routes, New and Old

Frankincense has been traded globally for thousands of years and constitutes one of the oldest globalized commodities. The original markets were in Egypt and Mesopotamia, sourcing resins from the Land of Punt, which is believed to be centered in modern-day Eritrea and/or southern Arabia. As Nigel Groom points out, trade was largely centered on the Arabian Peninsula, the Red Sea and the ancient Nabatean trade routes across the Empty Quarter to Makka, Jersusalem, Petra and on to Aleppo and Baghdad. It was not until the advent and growth of Christianity that the European market developed and the opening up of the Chinese market was largely due to bravery of Omani seamen and explorers like Marco Polo who sailed from Oman to China more than 400 hundred years ago. Today the markets in Asia have grown while North America has also been added to the traditional Middle Eastern markets.

Trade in *Boswellia* Papyrifera

B. papyrifera is the major source of resin for incense in Europe and orthodox churches in Ethiopia, Egypt and beyond. Due to low yields of between 1-2% and its rather unusual chemistry (dominated by octyl acetate rather than terpenes) the resin traditionally has been traded more for incense than for essential oil use; although this is beginning to change.

B. papyrifera, is supplied primarily from Ethiopia, Sudan and Eritrea. Eritrea was the main supplier of this type until well into the 20th century, but the decline in tree population and increasing demand have shifted the bulk of the trade to Ethiopia. Today, Eritrea supplies less than 450 tonnes per year; Ethiopian exports are often 10 times this number. Trade numbers for Sudan have been elusive, but estimates are consistently lower than Ethiopian numbers although much Sudanese resin is undoubtedly sent across the border to be exported through Ethiopian companies. The main market for this type of resin is in China where it is used in traditional medicine and more recently for incense. In addition, Indian extractors of Boswellic acids like Indfrag Biosciences and Alchem have reportedly been exploring Sudanese sources of resin for some years as *B. serrata* resin has become increasingly scarce.

Trade in *Boswellia* Sacra (Oman/Yemen)

Despite the classification of Omani, Yemeni and Somalian *B. sacra* as being the same species, the markets and trade routes are quite different. Once a major source of frankincense in antiquity, Oman and Yemen now play a relatively small, specialized role in the global frankincense trade. Yemen was traditionally the major trade route for frankincense, both from Oman as well as resin coming from Africa through Aden and Red Sea ports. Today, the ongoing civil war has all but eliminated both harvest and trade in Yemen. Virtually all legitimate trade is from Oman, where a few hundred tonnes of resin are harvested each year. To encourage local value addition, the Oman government has recently placed restrictions on the export of crude resin. A number of good essential oil producers such as SFC and Origo have, as a result, emerged as well as several high-quality cosmetic and perfumery companies like Olban, Majan and Raydan. The majority of essential oils produced in Oman is exported for use in the European cosmetic or U.S aromatherapy sector. A recent survey by the Environmental Society of Oman showed that despite government controls,

T-2. Estimated value addition from the sale of *Boswellia sacra* oil from Somalia (In USD/kg)

Price paid to harvesters (resin)	$ 30-60 (2-4/kg)*
Price paid to sorters/graders (resin)	$ 15-20 (1-2/kg)*
Price paid by local assemblers(resin)	$ 220- $ 330 (10-15/kg)*
Price paid by processor in Europe /US (oil)	$ 300-400 /kg
Price paid by consumer in Europe/US (oil)	S 1000-2000+/kg in 10ml bottle)

* Assumes 7% essential oil extraction rate

Ten Frequent Frankincense Myths and Legends

1. Frankincense is an ancient product used in the Catholic Church

While frankincense is indeed a wproduct used in church, its use is far more extensive and multidimensional. Frankincense is part of religious ceremonies worldwide, is used as modern and traditional medicine and aromatherapy, as a cosmetic and fragrance ingredient, as a preservative and purifier as well as many other household applications throughout the world.

2. Frankincense is from Arabia

One species of Boswellia, *B. sacra*, grows in Arabia. While the resin from this region has been harvested for generations, the vast majority of frankincense today comes from North Africa and India, especially Ethiopia and Somalia with Sudan and West Africa as emerging sources. *B. carteri* (see below) and *B. frereana* grow only in Somalia.

3. There is Boswellic acid in frankincense essential oil

Boswellic acids are non-volatile pentacyclic triterpenes, meaning that they are too large and heavy to be in essential oil. Extracts, such as CO_2 or hexane extracts, frequently contain Boswellic acids, but essential oils cannot and do not contain any of these heavy molecules.

4. The highest quality frankincense is from Oman, Somalia, etc...

Most regions that harvest *Boswellia* trees claim to possess "the best" frankincense. Quality, however, is subjective. The different species have dramatically different chemo types and aroma profiles; *B. papyrifera* smells nothing like *B. serrata*; while *B. frereana* and *B. sacra* are also quite distinct, etc. The highest quality frankincense is the one which best fits the needs of the consumer be it for fragrance, chewing, cosmetic or medicinal purposes.

5. Frankincense essential oil can treat cancer and many other diseases

Frankincense has never been used to successfully treat cancer in a clinical setting. A small number of in-vitro and rodent trials have shown some degree of cytotoxicity, but these are small, preliminary studies on cells in a petri dish. Boswellic acid has shown promise as an anti-tumoural agent, but frankincense essential oils do not contain Boswellic acids. Furthermore, despite seemingly endless claims for the health benefits of frankincense; from depression to infertility there are, till now, no well-structured human clinical trials to support these claims.

6. *B. carteri* and *B. sacra*...which is which?

B. carteri is officially recognized as a synonym of *B. sacra* with *B. sacra* referred by botanists as now the "official" name. Nevertheless, both are still commonly used for several reasons, not least of which is that they each tend to have unique scent and chemical profiles. *B. carteri* is used to refer to the populations of *B. sacra* growing in Somaliland and Somalia, while *B. sacra* are used to refer to the Arabian populations.

7. There is a species called *B. thurifera*

There is no officially recognized species called *B. thurifera*. The name was used to refer to several different species but today is recognized as an out-dated synonym of *B. serrata*.

8. Frankincense is sustainably harvested by generations of tappers who carefully manage the trees.

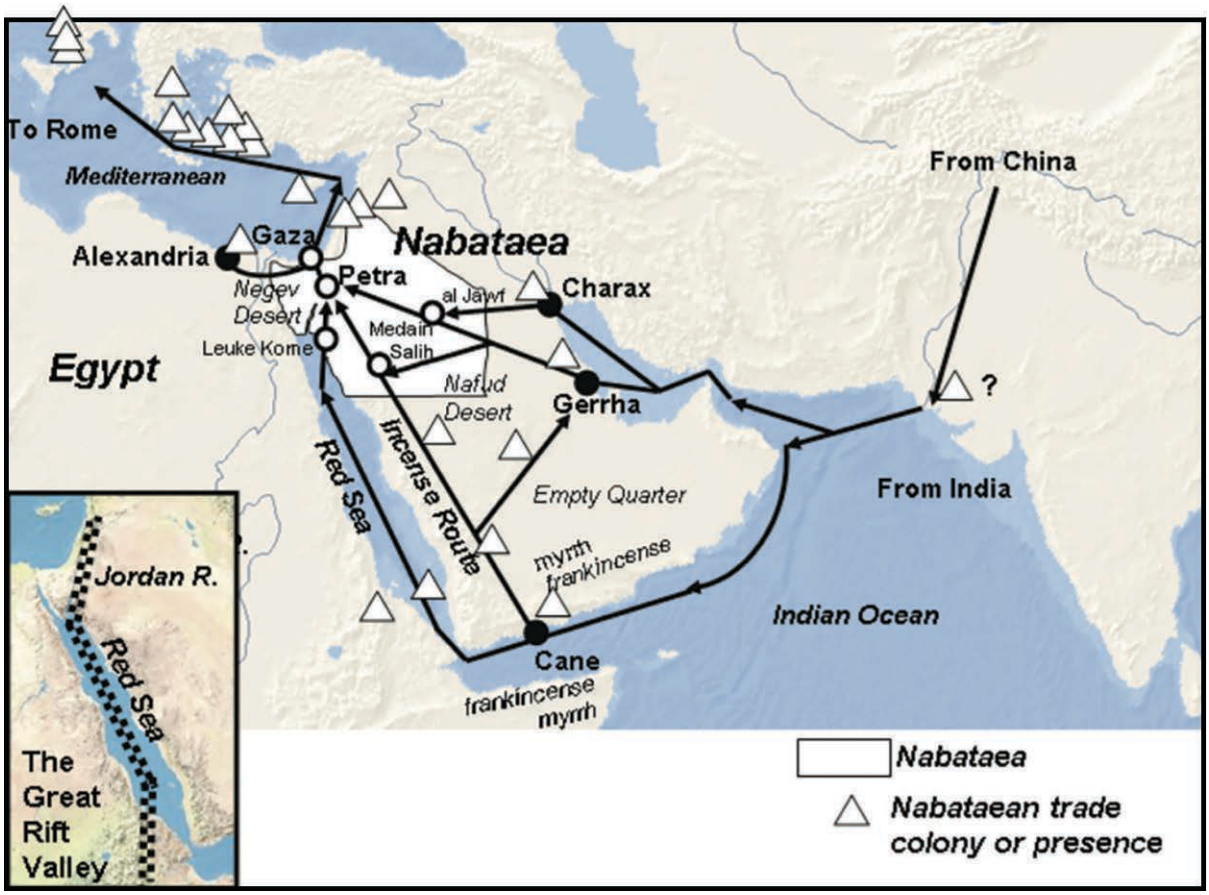
Despite the romantic "camel caravan" imagery, many of the places frankincense trees grow are in insecure areas where populations live in extreme poverty. While an overall independent assessment remains to be done, there is strong evidence that significant tree populations are suffering severe decline, due to a raft of complex interdependent factors, including fire, land conversion, unclear ownership, grazing animals, and over-tapping due to increased global demand, given a lack of additional income streams. A recent paper quoted in the New York Times in July 5th 2019, which draws upon decades of study in Ethiopia suggests that without dramatic changes in stewardship and harvesting practices, in some areas, the trees may be extinct within 20-30 years.

9. *Boswellia* cannot be cultivated

Most species of Boswellia are in fact relatively easy to cultivate and will grow readily from either cuttings or seedlings. Both government and private sector nurseries exists in Oman and while investment in frankincense cultivation has been surprisingly limited, modern drip irrigated frankincense plantations are currently found in both Oman and the USA!

10. Organic certification means the resin is harvested sustainably

Organic certification does not guarantee either the purity or sustainability of frankincense. Many commercial "organically labelled" *B. carteri* essential oils were shown recently to contain a mix of species, including the newly-discovered *B. occulta*. Organic certification simply refers to the fact that artificial fertilizers and pesticides have not been used in cultivation and no synthetic chemicals were applied during the processing of the resin.



Nabatean trade routes (source: Hull 2008)

a significant amount of resin is being exported by road to the Emirates for local use and export trade. Quantities are generally unrecorded as bags of resin are usually taken by car or small vans. The fact that the Oman government is stable and secure and has moreover made some strides towards developing sustainable supply chains for its frankincense has meant that several U.S and European companies including Young Living, DoTERRA and Neal's Yard Remedies have in the last few years switched some of their sourcing to Oman. We expect this trend to accelerate in the near future.

Trade in *B. sacra* syn. *B. carteri* (Somaliland/ Somalia)

The classic frankincense of choice for perfumery, *B. sacra* from Somalia was traditionally shipped through Aden in Yemen to markets in Europe and later to China. Although this oil is still used in perfumery Somalian *B. sacra* essential oil is now almost all exported for use in aromatherapy. This trade has grown significantly from ~200 tonnes in 1987 to an estimated 2000+ tonnes in 2018. With just a few companies driving large scale demand, most resins are shipped from Somaliland or Somalia to Dubai, Europe, the United States and a small amount to Kenya for distillation. North America is the current major market for aromatherapy products, although the Asian market is expected to grow significantly in the coming years.

Despite the fact that both France and Italy have been active in the horn of Africa for over a century it is surprising to note that not a single active distillation factory exists in the region. Almost all the resin from this area is distilled in France, the UK, or more recently Bulgaria and India (two distillation units have been established in Somaliland but it is presently unclear whether they are commercially functioning).

Boswellia Frereana

With a "sweet warm amber fragrance, highlighted by spice and floral notes" the majority of *B. frereana* is used for chewing purposes and for special types of incense. *B. frereana* is seldom use for distillation or extraction being expensive and generally limited in supply. Nevertheless there is a growing awareness in the west of this so called "King of Frankincense" and several American and European companies now stock it.

Boswellia frereana is also known as Coptic frankincense and is used in the Coptic Churches of Egypt and Ethiopia and elsewhere. But as Nigel Groom points out in his classic 1981 historical treatise, the vast majority is sold in Saudi Arabia for use by pilgrims going to Mecca for Haj. The traditional trade route was across the Red Sea to Yemeni ports and then to Jeddah and Makka. Due to the civil war, Dubai and Jeddah have to some extent replaced these Yemeni ports as the entry points into the Muslim whole cities.

Boswellia Serrata

High in a-thujene and so without the aromatic qualities of the other frankincense types, some of the resin from *B. serrata* is exported from India to the Chinese and other markets, but the majority is either distilled as a low quality essential oil or solvent extracted for the production of Boswellic acid used in herbal supplements sold in the Indian sub-continent and more recently in Europe where a human clinical trial showed that a topical application helped reduce arthritic pain and because *B.serrata* is the only species of *Boswellia* approved for use as a herbal supplement within the European Union. Recent reports by IUCN and several Indian conservation agencies however indicate that the increased demand for *B. serrata* for use in Ayurvedic medicine in Asia and the herbal industry in Europe and North America has resulted in stocks of this species being severely threatened in all harvest zones. Some attempts at cultivation have taken place in India and CSIR and other research centers are working on methods of enhancing resin yield from existing wild harvest trees, but the problem of sustainability remains.

Recommended Reading

Al-Aamri, M. (2015). *Sustainable harvesting of Frankincense trees in Oman*. Saarbrücken: LAP Lambert Academic Publishing.

Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., … Zuidema, P. A. (2019). Frankincense in peril. *Nature Sustainability*, *2*(7), 602. *https://doi.org/10.1038/s41893-019-0322-2*

DeCarlo, A., & Ali, S. (2014). Sustainable Sourcing of Phytochemicals as a Development Tool: The Case of Somaliland's Frankincense Industry. *Policy Innovations*.

DeCarlo, A., Dosoky, N. S., Satyal, P., Sorensen, A., & Setzer, W. N. (2019). The Essential Oils of the Burseraceae. In S. Malik (Ed.), *Essential Oil Research: Trends in Biosynthesis, Analytics, Industrial Applications and Biotechnological Production* (pp. 61–145). *https://doi.org/10.1007/978-3-030-16546-8_4*

Eslamieh, J. (2017). *Cultivation of Boswellia* (Second edition; N/A, Ed.). Phoenix, AZ: a book's mind.

Frankincense and Myrrh. A Study of the Arabian Incense Trade. 1981 **Groom, Nigel:** Published by London, New York: Longman, Librairie du Liban,,

Groenendijk, P., Eshete, A., Sterck, F. J., Zuidema, P. A., & Bongers, F. (2012). Limitations to sustainable frankincense production: Blocked regeneration, high adult mortality and declining populations. *Journal of Applied Ecology*, *49*(1), 164–173. *https://doi.org/10.1111/j.1365-2664.2011.02078.x*

Hull, B. Z. (2008). Frankincense, Myrrh, and Spices: The Oldest Global Supply Chain? *Journal of Macromarketing*, *28*(3), 275–288. https://doi.org/10.1177/0276146708320446

Hostanska K, Daum G, Saller R. Anticancer Res. 2002 Sep-Oct;22(5):2853-62.

Cytostatic and apoptosis-inducing activity of boswellic acids toward malignant cell lines in vitro.

Langenheim, J. H. (2003). *Plant Resins: Chemistry, Evolution, Ecology, and Ethnobotany*. Portland, Or: Timber Press, Incorporated.

Lemenih, M., & Kassa, H. (2011). *Management guide for sustainable production of frankincense: A manual for extension workers and companies managing dry forests for resin production and marketing*. Retrieved from *http://www.cifor.org/library/3477/management-guide-for-sustainable-production-of-frankincense-a-manual-for-extension-workers-and-companies-managing-dry-forests-for-resin-production-and-marketing/*