



Management guide for sustainable production of frankincense

A manual for extension workers and companies managing dry forests for resin production and marketing

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Acknowledgements

Current production levels of gums and gum resins in Ethiopia fall far short of the country's potential. Insufficient volumes and inferior quality drive prices down. This situation is particularly true for gum olibanum, commonly known as frankincense. Producing forest products at greater volumes, and of a consistent high quality, would lead to better prices, in turn creating an economic incentive for farmers and the country to sustainably manage the resource base. This management guide was produced to assist efforts to promote responsible dry-forest management and market-oriented production of frankincense for the export and domestic markets.

Following comments on an earlier version of the guide from experts at the Amhara Regional Bureau of Agriculture and Rural Development, we have reduced the technical details in order to focus primarily on practical aspects. We are also grateful to Drs Bo Tengnäs and Tony Cunningham and to Ato Girmay Fitwi for their technical comments on the draft.

We thank the Swedish International Development Cooperation Agency (Sida) for financing CIFOR's dry forest project in Ethiopia, which led to the creation of an earlier version of this guide. The Austrian Development Agency, by financing CIFOR's community forestry project in Ethiopia, enabled us to field test, revise and update, and print and distribute this guide to users.

Preface

Boswellia papyrifera (Del.) Hochst is a widespread multipurpose tree species of cultural, religious, economic and ecological significance in Ethiopia. It is one of the *Boswellia* species in the family of Burseraceae that yields the aromatic resin called frankincense or gum olibanum. Frankincense has been valued for its sacred and ceremonial uses since antiquity; during Roman times it was said to be as valuable as gold. The ecological significance and the socio-economic importance of *Boswellia* species were well recognised in Ethiopia's just completed Five-Year Development Plan. However, to date, efforts to promote responsible management of *Boswellia* woodlands to ensure sustainable production of frankincense have been limited. Inadequate knowledge regarding the management of these resources and the lack of a practical manual to guide extension workers and companies engaged in the production and marketing of frankincense are believed to have undermined the effectiveness and efficiency of such efforts.

This guide has therefore been prepared to contribute to the promotion of responsible management of

Boswellia forests in Ethiopia and to ensure the sustainable production and supply of frankincense. The specific objective of the guide is to provide technical information on (1) how to better manage the species in natural stands and in plantations, (2) how to properly tap the tree for increased and sustainable frankincense production and (3) how to improve and maintain product quality through better collection, handling and processing.

In preparing this guide, the authors drew on information in the literature, as well as their own research and field observations conducted in the major producing areas of Ethiopia during the past few years. It is hoped that the guide will be further updated and enriched in the future. In the meantime, the authors hope that the public extension service providers (at federal and regional levels) and non-state development actors will translate the guide into local languages for use by extension agents. This will assist efforts to improve management of the species and the quality of its products, and thereby enhance its contribution to local livelihoods and Ethiopia's national economy.

1. Introduction

The drylands of Ethiopia contain numerous tree and shrub species that produce commercial gums and gum resins. The most important of these species is *Boswellia papyrifera* (Del.) Hochst. *Boswellia papyrifera* is a deciduous multipurpose tree species of value for its commercial product, known as frankincense or gum olibanum. Frankincense has several traditional uses and a range of industrial applications, including in pharmacology, flavouring, beverages and liqueurs, cosmetics, detergents, lotions and perfumes. Ethiopia is one of the major suppliers of frankincense to the world market and earns considerable foreign currency from such exports. In the 2007/2008 Ethiopian fiscal year, the country exported 3834 tons of gums and resins, earning US\$ 5.2 million (Leminih and Kassa 2011).

Boswellia papyrifera thrives in marginal areas such as on steep and rocky mountains with shallow soils and low moisture. Its capacity to successfully establish itself in dry climatic and poor soil conditions makes it one of the best candidate plant species to restore degraded drylands, and to enhance the resilience and adaptation capacity of dryland communities to climate change.

Trade liberalisation has helped increase commercialisation of frankincense in Ethiopia. For instance, the frankincense trade volume increased from 2183 tons in the 2000/2001 Ethiopian fiscal year

to 3834 tons in 2007/08, and the number of producing and marketing companies grew from 9 to 32 during the same period (Leminih and Kassa 2011).

Excessive tapping of individual trees, expansion of crop and grazing land and forest fire threaten stands of *B. papyrifera* and the possibilities for sustainable production of frankincense. Declining regeneration and spatial shrinkage of *B. papyrifera* woodlands have been observed in much of the natural range of this species. As a result, there is an urgent need to develop and implement guidelines for responsible management of *B. papyrifera*.

Recent research into the dry forests of Ethiopia has furthered our understanding of the ecology, biology and silviculture of gum- and resin-producing species, particularly of *B. papyrifera*. This knowledge base must be used to improve management of the species.

The subsequent chapters of this guide describe the genus and species of this important plant, its distribution and reproductive ecology, and best practices for tapping the tree and post-harvest handling of its product, frankincense. The guide then sets out measures needed for sustainable production of frankincense, examines the need for property rights to institutionalise improved management systems, and proposes areas for further research.

2. Description of the genus and species

Boswellia papyrifera (Del.) Hochst belongs to the family Burseraceae, which contains up to 600 species in 17 genera (Fichtl and Admasu 1994). One of the genera, *Boswellia* Roxb., contains about 20 species of shrubs or small to medium-sized trees. The genus *Boswellia* is distributed across the dry regions of the tropics, with its presence in the African mainland extending from Côte d'Ivoire to north-eastern Tanzania. It also grows in northern Madagascar and in India. Its centre of diversity is in north-eastern tropical Africa (Vollesen 1989, Kuchar 1995, Gachathi 1997). Six species of *Boswellia* occur in Ethiopia: *B. microphylla*, *B. neglecta*, *B. ogadensis*, *B. papyrifera*, *B. rivae* and *B. pirrotae*. All of these, except *B. pirrotae*, are tapped for gum olibanum.

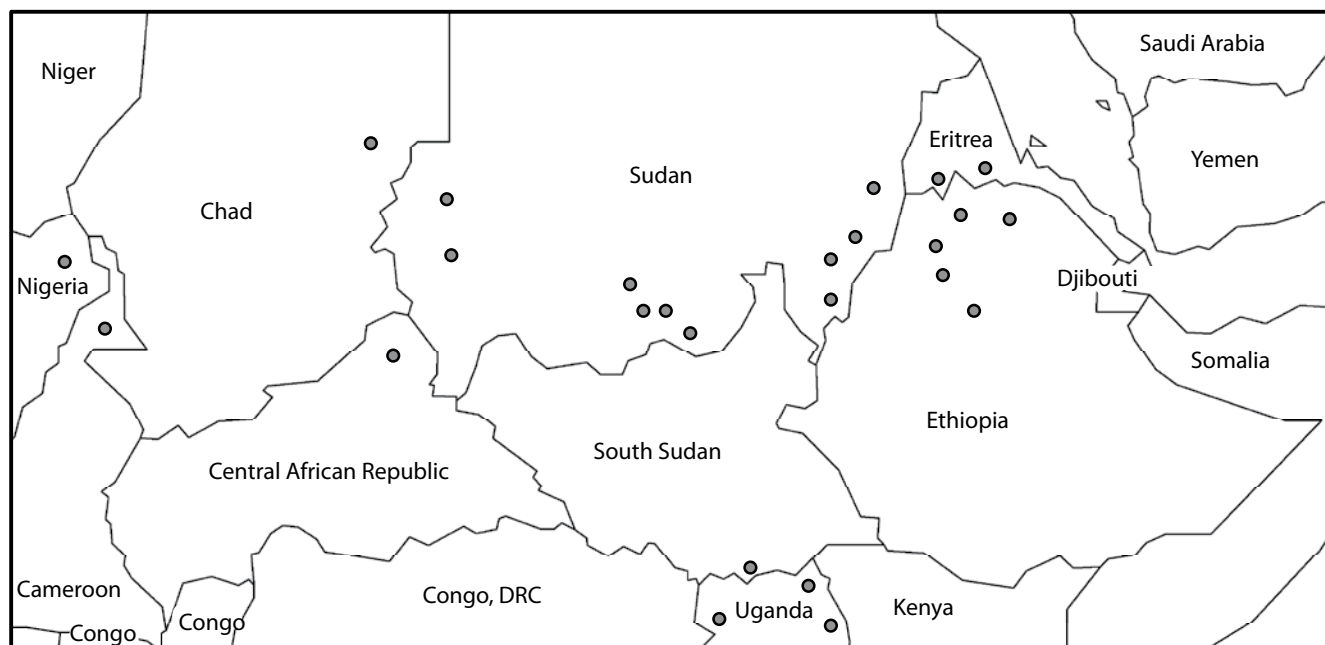
Boswellia papyrifera is the chief source of frankincense produced in Ethiopia. Frankincense from northern Ethiopia is known and traded on international

markets as Tigray (Eritrea) type frankincense (Lemenih and Teketay 2003). *Boswellia papyrifera* trees can attain a height of up to 20 meters. The large compound leaves have 6–8 pairs of leaflets plus one at the tip. Each leaf is oval, 4–8 cm long and densely hairy underneath. The edges of the leaves are sharp- or round-toothed, and sometimes double-toothed. The sweet-smelling flowers develop on loose heads at the end of thick branchlets (Figure 1), appearing before the new leaves. The red flower stalk, which can reach a length of up to 35 cm, bears white-pink flowers with 5 petals and 10 yellow stamens. The pear-shaped fruits are a red capsule of about 2 cm long, divided into 3 valves, each containing 1 hard seed. The fruits are borne at the ends of the reproductive branchlets. The outer bark often peels off in thin, papery flakes, and the inner bark is greenish. When wounded, the bark exudes a watery aromatic resin, which slowly hardens to a resin with exposure to air.



Figure 1. A *B. papyrifera* tree (centre), its flowers (upper left), leaves (right), bark with a frankincense tear (lower left) and flaking bark (centre bottom)

3. Distribution of *Boswellia* species



● Reported occurrence of *Boswellia papyrifera*

Figure 2. The distribution of *B. papyrifera* (Del.) Hochst in Africa

Source: Adapted from Hepper (1969) and Vollesen (1989)

In Ethiopia, *Boswellia* species grow naturally in various vegetation formations. The species are predominantly found in the *Terminalia–Combretum* broad-leaved deciduous woodlands, the *Acacia–Commiphora* small-leaved deciduous woodlands, and among lowland semi-desert and desert vegetation. These vegetation types are found in the northern, north-western, western, eastern, south-eastern and south-western lowlands as well as along the major river gorges such as Blue Nile, Tekeze and their tributaries.

Boswellia papyrifera is restricted to the *Terminalia–Combretum* broad-leaved deciduous woodlands of the north, north-west and some of the northern major river gorges. In these areas, it covers wide ecological and altitudinal ranges, occurring in areas at an elevation range of 220–1800 m above sea level, with an annual rainfall of 100–800 mm and a mean annual temperature of 25–40 °C. *Boswellia papyrifera* is predominantly found in Tigray, Amhara and



Figure 3. *Boswellia papyrifera* stands on a steep, rocky slope

Benishangul-Gumuz Regions, although its presence has been reported on a smaller scale in some parts of Oromiya and Afar Regions. According to available estimates, about 1.7 million ha of woodlands holding *B. papyrifera* as their main species occur in 3 administrative regions. In Africa generally, *B. papyrifera* is found in Cameroon, Central African Republic, Chad, Eritrea, Ethiopia, Nigeria, Sudan and Uganda (Figure 2).

Boswellia species grow on steep and rocky areas, exposed sites, gullies and lava flows or sandy river valleys with very shallow soils (Figure 3). They are well adapted to red sandy/rocky soils and do well in soils with poor fertility. They also grow densely on steeper and rocky (rather than gentle) slopes and on well drained landscapes.

4. Flowering, seed production and propagation

4.1 Flowering

The *B. papyrifera* tree produces leaves with the first few showers of small rains, around April in north-western Ethiopia. It sheds leaves at the beginning of the dry season, in October–November. Flowering commences in October. Most of the fruits begin to mature in November and fall from the tree before the second half of January. The sweet-smelling flowers on the red flower stalk (Figure 4) usually develop before new leaves. Recent observations have shown that *B. papyrifera* displays a slightly different phenology in different sites, according to environmental conditions, particularly rainfall. Thus, the phenological description given here may not apply to the whole geographical range of the species.



Figure 4. Abundant pinkish flowers of *B. papyrifera*

4.2 Seed production

Normally, *B. papyrifera* bears seeds in abundance, with 44 000–64 000 seeds per kilogram. Purity is high, usually more than 90%. *Boswellia papyrifera* seeds germinate readily and have a high germination rate. They require no pre-treatment nor do they exhibit dormancy. However, treatment by soaking in cold water for 12 hours has been reported to induce greater and faster germination of the seeds (Eshete and Alem unpub.). By contrast, the treatment of seeds with boiling water or with concentrated sulphuric acid, as conventionally used, suppresses germination.

Inter-annual seed viability (germinability) differences have been observed in the species. This raises the concern that *B. papyrifera* might produce non-viable or dormant seeds in some years, an aspect that merits further investigation. A high incidence of insect attack and a high proportion of seeds without embryos have been observed in seeds from heavily tapped and old trees (Ogbazghi *et al.* 2006, Rijkers *et al.* 2006). Therefore, seed collection from old trees and intensively tapped stands should be avoided. Instead, seeds must be collected from medium-sized, healthy and untapped trees, if available. If not, seeds should be collected from sufficiently rested trees.

Seeds of *B. papyrifera* can be stored under various storage conditions such as at room temperature for a long period without significant loss of viability provided that the moisture content of the seed is kept low (6% or less) (Eshete *et al.* unpub.). For instance, at a moisture content of 6%, germination of more than 94% was obtained after 1 year of storage at room temperature. This suggests that the seeds of *B. papyrifera* can be stored in rural nursery stores, which are convenient and cheap.

4.3 Propagating *B. papyrifera*

Boswellia papyrifera is known to propagate via several means: from natural seed germination (wildings), nursery seedling production and transplanting, rooted cuttings and root sprouts/suckers. However, artificial establishment of the species is not a common practice in Ethiopia.

4.3.1 Seed-based propagation

a. Seedling production in nurseries

Experience with nursery management of *B. papyrifera* seedlings is limited. However, observations show that the seedlings can be raised in nurseries without problem (Figure 5), as with many other dryland species. Seeds readily germinate and seedlings grow vigorously on various soil types. However, a higher proportion of sand than normally used in nursery soils is recommended (e.g. 3:3:1 soil ratio). This is because *B. papyrifera* demands a well-drained and aerated soil environment. Furthermore, watering should be less frequent than is usually applied to the seedlings of many other species. Because *B. papyrifera* is a dryland species, it tends to develop a deep taproot in the nursery, with a ratio of root to stem growth of around 3:1. Hence, *B. papyrifera* seedlings require root pruning. On average, seedlings reach plantable size within 4–5 months.

b. Propagation from wildings

A large seedling population is often observed in the natural stands of *B. papyrifera*, particularly during



Figure 5. Two-month-old seedlings of *B. papyrifera* in a nursery

the rainy season (Figure 6). However, for reasons that are still largely unknown, most of the seedlings fail to survive during the dry season. This has resulted in minimal recruitment in natural stands to replace old and dying trees. *Boswellia papyrifera* is highly palatable for livestock and wild herbivores, and the seedlings are frequently browsed and trampled due to uncontrolled grazing in *Boswellia* forests. Fire also causes considerable damage. Wildings can be saved by transplanting and replanting them in nurseries and managing them until they achieve significant strength for field replanting. In this way, wildings can be used in managing the natural stands of the species.



Figure 6. Wildings of *B. papyrifera* in their natural environment (left from Abergelle, right from Metema) (Photos: Emiru B. and Mulugeta L.)

c. Planting and protecting seedlings and saplings

Seedlings of *B. papyrifera* must achieve sufficient vigour before being planted out. The seedlings should also be hardened off well before planting out as the juvenile seedlings may be unable to withstand the harsh environmental conditions of arid and semi-arid areas. Planted seedlings and saplings must be protected from grazing animals, termites, rats and fire. If possible, constructing fire breaks and fencing are recommended to protect seedlings. To protect planted seedlings from termites, use of insecticides, mainly bio-insecticides, is suggested.

4.3.2 Propagation through rooted cuttings

In experiments, planting of nursery-raised seedlings of *B. papyrifera* demonstrated a poor field establishment success rate. Even when protected against grazing and fire, seedlings failed to exhibit good survival. Vegetative propagation, particularly macro vegetative propagation with rooted cuttings, is expected to result in successful field establishment of the species including plantation forest establishments. As with most deciduous tropical plants, *B. papyrifera* propagates from branch cuttings (Figure 7). In fact, unlike other asexual propagation methods such as grafting, budding and micro propagation (tissue culture), macro cutting techniques are easy, cheap and quick. Macro cuttings can take root in an open environment when planted directly in the field.

To use rooted cuttings for propagation of *B. papyrifera*, the materials should be collected from healthy, mature and vigorous donor plants. Factors that significantly affect the success of

rooted cuttings are the season when collection and planting are carried out and the dimensions of the cuttings. Collection and planting should be done during the dry season when the donor trees are dormant. For instance, in Tigray and Metema, the best months to collect and plant cuttings are February and March. Cuttings used in this exercise were reported to be about 1.0–1.5 m long and with a circumference of about 20 cm. Experiments have been initiated to explore options to minimize the height and diameter of cuttings required for successful vegetative propagation.

Branch cuttings should be planted immediately to protect them from desiccation/dehydration. Planting pits should be 45–60 cm deep with a diameter of at least 20 cm. The thicker side of the branch cuttings should be sliced at a slanting angle of about 45° and the cuttings should be inserted into the soil at a leaning angle in order to allow the cambial layer to fully touch the soil. The opposite end (the tip) must be covered with water-repellent coatings and treated with fungicide to avoid decay and dehydration. The fine soils removed from the pit should be placed back into the pit and thoroughly packed to reduce air voids. The soil around the pits should be scrapped and heaped around the cutting to form a small mound to avoid water accumulation on the pit. Weeding and hoeing are necessary, and the cuttings should be protected from animals (e.g. by fencing) and insect pests such as termites (e.g. by using anti-termite chemicals). Latex from *Euphorbia abyssinica* can be used to treat *B. papyrifera* branch cuttings to stimulate and enhance rooting and survival. The latex is known to contain indoleacetic acid, an auxin controlling apical

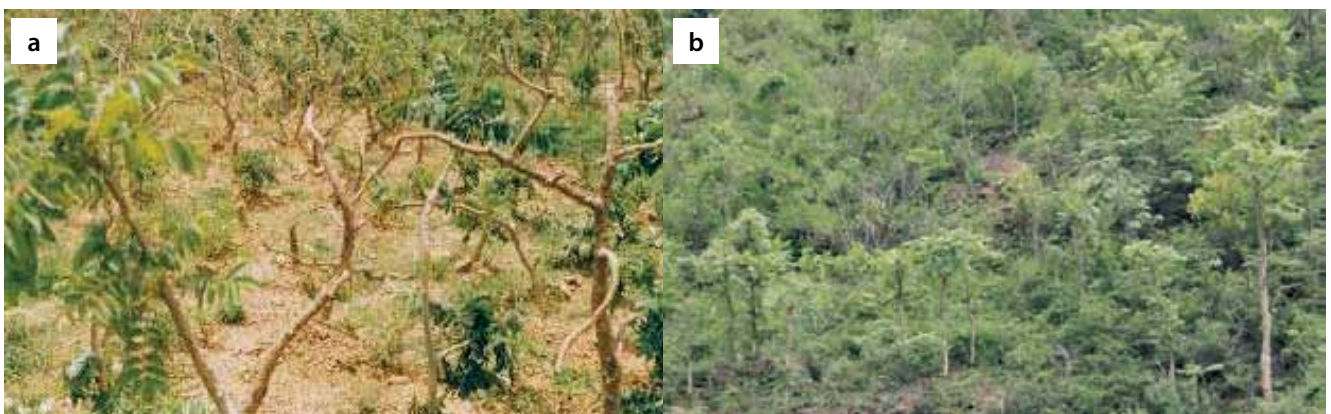


Figure 7. *B. papyrifera* established from cuttings at a research station in Tigray (a) and under field conditions in the Blue Nile gorge (b)

dominance and lateral rooting, as well as indoleacetic acid metabolites and conjugates (Negussie *et al.* 2009).

4.3.3. Propagation through root suckers

Boswellia papyrifera can also be reproduced using root suckers. This method appears to play a considerable propagation role in the natural environment of the

species. In this type of *B. papyrifera* propagation, the exposed root of a mature tree can initiate a root sprout, which, if protected against damage by animals and insects, can grow into a mature tree (Figure 8).



Figure 8. Root-sprouted *B. papyrifera* in its natural stand in Metema

5. Tapping and post-harvest handling

5.1 Tapping

Traditionally, frankincense from *B. papyrifera* is produced through artificial wounding of the trees, a process called tapping. Tapping is carried out during the dry season. However, it is not clear whether the dry season is chosen out of convenience for tappers or because it is dictated by the physiology of the tree. Traditional tapping¹ involves slightly shaving the external layer of the bark and forming a circular wound of about 1–2 cm high, 1–1.5 cm wide and 0.5–1.0 cm deep. Usually 3 tapping spots are made on each side of the tree, starting at about 0.5 m from the base of the stem (Figure 9). More than 3 tapping spots can be made depending on the size of the tree.

Tapping is a cyclical operation that is repeated every 15–20 days after the first tapping. During the subsequent tapping cycles, older wounds are refreshed and the blaze is moderately widened by removing more bark from the upper edges of the former wound

and by carving down 2 cm of the lower edge. Tapping continues until the onset of the rainy season. Thus, a tree is tapped 8–12 times a year, and at the end of the production year each wound may attain a width of about 10 cm or more (Figure 10).

Increasing the number of tapping spots in a tree increases the overall annual yield of frankincense per tree, but it affects the tree's vitality and interferes with its reproductive biology. If a tree has too many wounds, it can produce tears of resin that are too fine or dusty, and thus less attractive to buyers. Indeed, an optimum tapping intensity needs to be applied to ensure a compromise between tear size, total frankincense yield and impact on the tree. The recommended tapping intensity per tree is a total of 6 spots for trees of < 20 cm diameter at breast height (DBH), a total of 12 spots (3 spots on each of the 4 sides) for trees of medium DBH (20–30 cm) and a total of 16 spots (4 spots on each of the 4 sides) for trees > 30 cm DBH.

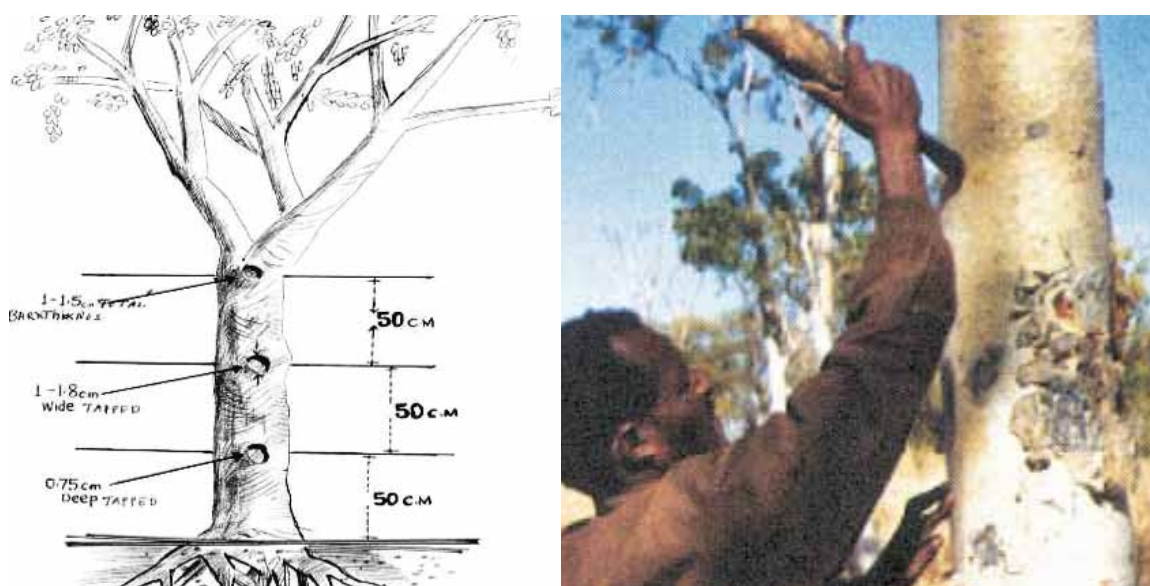


Figure 9. Schematic presentation of recommended distances between tapping sites (left) and the tapping practice (right) (Figure: Girmay F., Photo: Wubalem T.)

¹ Tapping is done using a sharp metal tool such as an axe. In northern Ethiopia, tappers use a special tool known as a *mingaf*.



Figure 10. *Boswellia papyrifera* trees tapped for 1 year (left), 2 years (centre) and more than 2 years (right)

Another important element in managing the tapping regime is renewing the wound at the correct interval of days. If wounds are not renewed at the correct intervals, the old wounds may heal completely. Wounding after the older wounds heal causes the tree to delay exuding the resin. This is almost equivalent to starting the whole process of tapping all over again, which will result in reduced overall annual yield and increased production costs.

Estimates of annual frankincense yield per *B. papyrifera* tree vary considerably. For instance, Tadesse *et al.* (2004) reported a range of 6.7–451.4 g frankincense per tree per year. Eshet and Alem (unpub.) reported a frankincense yield of 207–352 g per tree per year. The variation in yield per tree is attributed to tree size (DBH), tapping intensity and site conditions. Generally, trees with a bigger DBH provide higher frankincense yield than trees with a smaller DBH. Similarly, increased tapping intensity increases frankincense yield per tree. Frankincense yield can be doubled or tripled by increasing the number of tapping spots per tree from 4 to 12, but this may be unsustainable. For this reason, it is recommended that smaller trees be wounded in

only a few spots, with a subsequent increase in the number of wounding spots as the tree increases in girth. Wide variability in frankincense yields is common among trees of similar sizes growing in the same environment (Tadesse *et al.* 2004). Research indicates a weak correlation between tree dimensions (e.g. DBH, height) and frankincense yield for any given tapping intensity (Tadesse *et al.* 2004, Eshete and Alem unpub.). Developing a predictive model to estimate frankincense yield for a tree or a production area using such weakly correlated relationships would be misleading.

5.2. Post-harvest handling

Using locally made collection vessels, tappers manually pick the tears of solidified frankincense resin from individual trees (Figure 11). These tears are seasoned by spreading them out on mats under temporary shades constructed in the field. Seasoning is an essential process for avoiding clumping of the tears. The seasoned tears are then packed in sacks and transported to permanent warehouses for further processing.

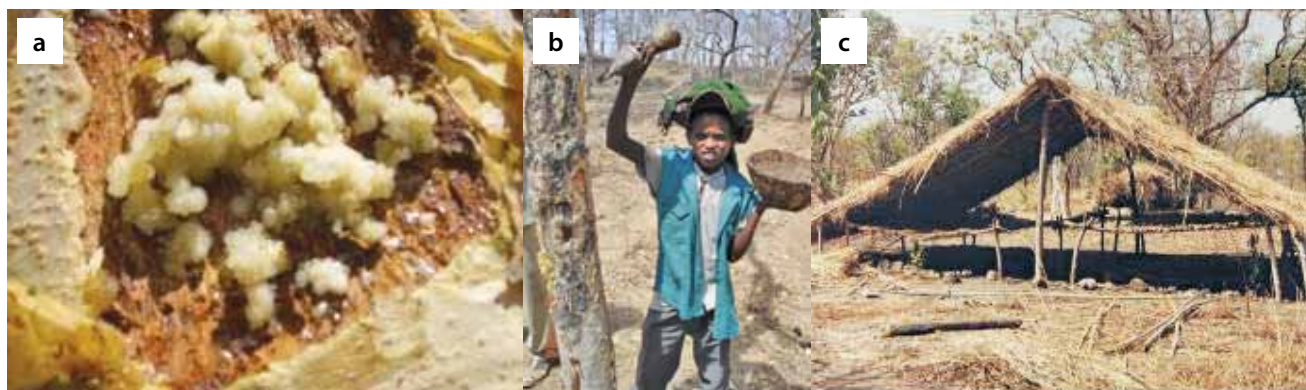


Figure 11. Frankincense tears oozing through a wound (a); tool and collection vessel for collecting frankincense (b); and product seasoning under shade at the production site (c)

Further processing at warehouses involves cleaning any foreign materials (such as grass, leaves or small stones) off the frankincense. During this process of manual sorting and grading, the frankincense is sorted into 7 grades based on colour and tear size (Table 1).

Cleaning, sorting and grading play an important role in improving product quality. However, current traditional post-harvest handling practices have several shortcomings that negatively affect product quality. Major problems include: improper storage; seasoning in unclean conditions; use of inappropriate or contaminated containers; and poor hygienic conditions during sorting and cleaning. One common problem, for example, is that frankincense is stored and/or transported with volatile substances such as petroleum products. Moreover, frankincense collected from trees is often kept in the field under high temperatures for a prolonged time in perforated (not airtight) containers. These improper post-harvest handling practices result in the loss of significant

proportions of volatile essential oils and subsequent reduction in the quality of the frankincense.

Delivery of high-quality frankincense requires adherence to the following practices.

- Clean and appropriate vessels should be used for field collection and airtight containers for storage and transport of the product.
- Storage rooms/shades should be as clean as possible and kept at a relatively moderate temperature.
- Seasoning should be carried out on clean materials free from dust and grass.
- Storage or transport with substances such as petroleum, oil and salt should be avoided.
- Collectors and cleaners should maintain cleanliness to avoid contamination.
- Frankincense fallen from the trees and mixed with dust should be avoided if possible. If not, such products must be collected separately and cleaned thoroughly.”

Table 1. Grades of frankincense from *B. papyrifera*

Grade	Description	Expected proportion from 1 quintal of unprocessed frankincense (%)
1 A	Size \geq 6 mm; white	22
1 B	Size \geq 6 mm; creamy white	9
2	Size 4–6 mm	11
3	Size 2–4 mm	8
4 Special	Any size; brown	19
4 Normal	Any size; black	17
5	Powder and bark; no size limit	14

Following such best-practice guidelines will make it possible to supply better-quality, higher-value frankincense to the market.

Recent studies have failed to distinguish differences in chemical composition between the different grades of frankincense. This suggests to producers and exporters that the tradition of grading based on size and colour is merely a physical requirement and may have little to do with chemical composition. In fact, frankincense of all grades is processed into more or less the same end products. This indicates that at least partial value-added processing, such as essential oil extraction, will provide better returns than selling the raw frankincense, especially for products labelled as

low grade and sold for lower prices. Essential oils can be extracted in many ways, such as by mechanical or solvent extraction, vacuum distillation and stem/hydro distillation.

Processing of frankincense for the production of essential oils is simple and does not require sophisticated equipment. The frankincense is placed in water in a distillation apparatus, and the water is maintained at boiling point. The steam containing the dissolved or vaporised volatile oils from the frankincense condenses and is collected in a basin, in which the oil floats on top of the water. This technology can be adopted at the farmer level using a prototype apparatus.

6. Measures for ensuring sustainable frankincense production

Boswellia papyrifera forests are facing several challenges. Four direct factors affecting *Boswellia* forests are: (1) clearance for crop production by commercial farmers and resettled smallholder farmers; (2) overgrazing; (3) intensive and improper tapping; and (4) increasing forest fire (Gebrehiwot *et al.* 2002, Eshete *et al.* 2005, Lemenih *et al.* 2007). Underlying factors are high population influx, mainly through resettlement schemes, coupled with a weak institutional environment for regulating access to and management of dry-forest resources. These factors have led to uncontrolled conversion and unregulated exploitation of *Boswellia*-dominated woodlands, resulting in widespread deforestation. Addressing these challenges is a major requisite to ensure sustainable production and supply of frankincense. Developing stronger local institutions, in which local communities take the lead, and establishing sustainable market links are essential steps to achieving successful frankincense-based enterprise development at the local level. Market links may also create an economic incentive for farmers to responsibly manage dry forests and sustain the environmental services from woodlands. The following sections present specific management-related measures for sustaining frankincense production.

6.1 Reducing conversion of woodlands

Agricultural land expansion as a result of human population pressure, mainly from state-sponsored resettlement programmes, is a growing threat to *B. papyrifera* forests. Conversion of *B. papyrifera* forests to farmland is taking place at an increasing rate each year (Figure 12). For instance, from 2003 to 2005, 18 586 households were officially settled in Metema district through the Amhara Regional State Resettlement Programme. Upon arrival, each household was allocated 2 ha of land for farming. This means a total of 37 172 ha of the dry forest

containing predominantly *B. papyrifera* was cleared. Furthermore, information obtained from Metema district office shows that during the past 20–30 years, an area equivalent to 303 180 ha of *B. papyrifera* woodland has been converted to cropland. Similarly, in Tigray Region, Gebrehiwot (2003) reported that more than 177 000 ha of *Boswellia* woodland had been destroyed during the previous 20 years. If this high rate of forest clearance continues, ensuring a sustainable supply and production of frankincense in the future will be difficult.

6.2 Managing forest fire

Controlled burning is part of a woodland management practice that serves many purposes. It is used to reduce bush encroachment in favour of grass and to control animal parasites such as ticks. However, in recent years, fires have been intensified in *B. papyrifera* woodland areas. Not only farmers but also tappers set fire just to clear the undergrowth or to reduce the risk of encountering snakes or other wild animals. Local people also set fires while harvesting wild honey or clearing woodlands for farmland. These fires can spread, causing damage to woodlands, including to emerging seedlings and saplings



Figure 12. Cropland expansion by clearing *B. papyrifera* woodlands in Metema district

(Figure 13). As these areas have no organised fire control mechanism, damage recurs each time forest fire incidence occurs. It is therefore crucial to raise awareness and establish local institutions responsible for reducing fire incidence and damage in these areas.

6.3 Improving tapping methods and timing

Tapping can cause damage to trees if done at high intensity or by inexperienced tappers. Damage arises because tapping exposes trees to infectious attack by insects and other pathogens (Figure 14), reduces tree vigour and increases susceptibility to windfall. Moreover, increased tapping intensity of *B. papyrifera* trees reduces their sexual reproduction by affecting the carbon allocation between frankincense production, healing of wounds and fruit and seed setting (Rijkers *et al.* 2006). Tapping is practised only during the dry season, apparently because this season is convenient for collectors. Trees are in dormant state during this period, and there is a large carbon reallocation to frankincense production. This

carbon reallocation greatly weakens the trees and limits their production of viable seeds. In general, intensively tapped stands produce less viable seeds, which can negatively affect natural regeneration. As untapped trees produced very healthy and viable seeds, it is recommended that, for all production systems, a selection of trees be left untapped to serve as seed sources (mother trees). If this is difficult to implement, then allowing a sufficient resting period of 3–5 years after trees/stands are consecutively tapped for a couple of years can enable the trees to regain vigour and vitality.

6.4 Maintaining a viable *Boswellia* population

Current mismanagement of *B. papyrifera* appears to be affecting the population structure of the species. In some sites, reports indicate that 65% of the total population falls in the diameter range of 10–20 cm (Gebrehiwot 2003). Under normal conditions the youngest population of less than 10 cm should have constituted the largest percentage of the population.



Figure 13. Effects of fire in *B. papyrifera* forests on trees, seedlings and saplings



Figure 14. Improper tapping (a) exposes the inner bole of the tree to decay (b) and predisposes the tree to parasite attack (c)

The low density of individuals in smaller diameter classes suggests that regeneration and seedling recruitment are inadequate. This potentially poses a threat to sustainable resin production from *B. papyrifera*. Managing certain woodlands to support regeneration and recruitment of *B. papyrifera*, by controlling open grazing and fires and by nursing seedlings, is essential for maintaining viable populations, which, in the long run, is key to ensuring a sustainable supply of frankincense.

6.5 Other management-related recommendations

Generating sustainable benefits from the gums and gum resins subsector depends on the reconciliation of biological sustainability and commercial viability. Several possible approaches for increasing the production and quality of frankincense are available, such as using appropriate collection tools and methods, improving the management of natural stands and establishing plantations to increase production and improve productivity.

6.5.1 Improving harvesting methods

As discussed above, improper tapping adversely affects trees. However, in Metema area for instance, some companies bring in young and unskilled tappers, who do not treat the trees properly. Therefore, to minimise the impacts of improper tapping on the trees, it is necessary that workers be equipped with appropriate tools and adequate training on proper tapping practices. The lack of

trained labourers in production areas is exacerbated by competition for labour from nearby commercial farms (Lemenih *et al.* 2007).

6.5.2 Management of natural stands for sufficient regeneration

At present, frankincense is produced from natural populations of *B. papyrifera*. Ensuring sustained production of frankincense from natural stands requires managing the resource in a responsible way. This involves, among others, managing the regeneration of *B. papyrifera* in natural forests, through appropriate management of the ecosystem. Management options that support adequate regeneration of *B. papyrifera* are regulated frankincense harvest and intensive management of the stands.

- a. **Regulated harvesting.** Regulating tapping, either by allowing a sufficiently long resting period or by reducing tapping intensity, or a combination of these, is necessary to promote regeneration. This technique is cheap and simple, but it has the drawback of reduced economic gains in the short term. To optimise economic gains, this management option can be integrated with other economic activities such as livestock production. Grass and browse, including *B. papyrifera* leaves, can be used as livestock feed. Alternative strategies for regulated harvesting are to adopt **selective harvesting** or **rotational harvesting**. Selective harvesting involves selectively leaving untapped a sufficient number of healthy parent

trees throughout the landscape. These trees then serve as sources of viable seeds to enhance regeneration. These trees and their surroundings must be protected against fire and grazing to protect emerging seedlings. Rotational harvesting involves rotating production centres to allow some sites to sufficiently rest while production is taking place in other sites. The system can be based on collectors' traditional knowledge as there is a lack of scientific research on the appropriate rotational period.

- b. **Intensive management.** This management option involves adjusting the intensity of harvesting using silvicultural practices to better manage natural propagation of the species. Such management involves site preparation, artificial seeding, shading and watering seedlings and protecting seedlings against grazing, fire, rats and termites. Other management applications such as thinning and coppicing can be applied to ensure rapid growth and high yields. However, knowledge on appropriate management techniques for the species is still very limited, and further research is needed to determine how best to manage the resource base.

6.5.3 Domestication and plantation establishment

Boswellia papyrifera has not yet been domesticated in Ethiopia. The domestication of the species and its widespread plantation on private farmlands, community forestlands and degraded wastelands could enhance the contribution of the subsector to local livelihoods and the national economy in general. *Boswellia papyrifera* must be domesticated to achieve sustainable frankincense production

for export markets. As this species successfully establishes itself and thrives well even on marginal and degraded lands, it is more appropriate to plant the species on marginal lands and degraded community forestlands where cultivation of crops has little success. There exist some agroforestry systems where gum and incense tree species are integrated with other production systems such as crop or animal production or both. For instance, in the Sudan, *A. senegal* is intensively managed in agroforestry systems. Although to a very limited extent, in some parts of Tigray, *B. papyrifera* trees are maintained on farmlands as parkland agroforestry trees and used for the production of frankincense. There is huge potential in this regard, but this must be supported by action-oriented research that helps build local capacity and addresses possible constraints.

6.5.4 Improving product handling, quality control and value-adding

The most important aspect that needs to be addressed in frankincense production and marketing is quality control. This calls for improvement in storage, handling and transportation conditions. Important components of frankincense from *B. papyrifera* are the essential oils, which are partly volatile when exposed to the high temperatures prevalent in the production areas. Storing products under excessive temperatures should be avoided, and airtight containers are recommended to maintain volatile oils. Harvested quantities should be processed as soon as possible, packed in airtight containers and stored at relatively low temperatures. Once the products are properly collected, options for value-adding must be explored; those that are economically feasible need to be pursued.

7. Property rights and institutionalisation of responsible management systems

It is not the intention of this guideline to compare and contrast property rights arrangements and argue that one form of arrangement is better than another. However, forestry is a long-term investment; it therefore requires secure ownership and clearly defined property rights, as well as appropriate law enforcement that is effective, efficient and suited to local conditions. Indeed, sustainable management of *B. papyrifera* requires a policy environment that grants local communities rights to access and benefit from dry forests, with concomitant and enforceable responsibilities to sustainably manage the resources. Unless farmers make clear economic gains from *B. papyrifera* stands, it would be unrealistic to expect them to invest time and resources in protecting and managing the species.

Responsible management of *B. papyrifera* and the collection of frankincense require more effective institutional arrangements and secure land and tree tenure. For instance, in Metema district, local authorities prohibit local people from gaining access to forests and forbid tapping. As communities report, this policy reduces any incentives local people might have to protecting local woodlands. Rather, it has encouraged clearance of the woodlands (Figure 15)

and their subsequent conversion to crop farming, as this has greater economic returns for farmers.

In some cases, the natural stands that locals are prohibited from accessing have been passed to outsider concessionaires. Stands allocated to concessionaires are said to have been over-harvested because of lack of effective monitoring institutions and mechanisms. Furthermore, there are discrepancies between the regional guidelines and the observed behaviours of actors on the ground regarding the rights and responsibilities of tappers, and the practices of local government authorities, which are supposed to be monitoring the management of forests given under concessions.

In areas where locals are granted access rights, such as in Tigray, forest patches are harvested on a rotational basis by households with practically no regulation of intensity or frequency of tapping. Furthermore, producing households are often expected to sell their produce to the cooperative at non-negotiable prices. Without proper controls on access and a fair pricing system, this system will reduce incentives to manage forests responsibly.



Figure 15. Clearance of *B. papyrifera*-dominated woodlands for crop farming in north-western Ethiopia

8. Issues for research

Supporting the economic and ecological roles of *B. papyrifera* requires further applied research. The most urgent topics for research are: management of natural stands; value-added processing; eco-physiology and ecology of the species; marketing and trade of frankincense in general and enhancing the survival and recruitment of emerging seedlings in particular; and how these interact with sustainable resource base management and institutional arrangements for sustainable management of the resource base. Furthermore, there is no scientific

justification for the choice of the dry season as an appropriate time for tapping. Research is required to investigate whether the production of frankincense can also be carried out during the rainy season, and whether dry season harvesting is safer for the tree or affects the quality and quantity of resin produced. It would also be useful to explore options for integrating the species into existing land use systems in various forms of agroforestry or plantation production. This requires improving trees both for productivity and for quality as well as improving propagation techniques.

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This guide is intended for frankincense producers, extension workers and companies engaged in producing frankincense. Gum olibanum (frankincense) from *Boswellia papyrifera* (Del.) Hochst has been collected and traded for centuries. Although production levels in Ethiopia fall far short of the country's potential, export volume and earnings from frankincense have been significantly increasing since the late 1990s. But knowledge regarding the biology and ecophysiology of the tree, the frankincense collecting process and post-harvest handling remain largely inadequate.

This guide contributes toward filling this gap by providing technical information in three specific areas: how to better manage the species, how to properly tap the tree for increased and sustainable production and how to improve and maintain product quality through improved collection and handling. Section One of the guide introduces dry land areas of Ethiopia. The second and third sections describe the genus, the species and the distribution of *Boswellia* species. Flowering, seed production and propagation aspects are treated in Section Four while Section Five covers tapping and post-harvest handling of frankincense. Measures for sustainable frankincense production are discussed in Section Six whereas property rights and institutionalisation of responsible management systems are discussed in Section Seven. Finally, Section Eight briefly outlines key issues that require further research. Effective use of information in the guide can help in sustaining supply of frankincense by increasing income of producers and enhancing the responsible management of *Boswellia* forests in Ethiopia.

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