Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Disponible on line en www.inia.es/srf

Investigación Agraria: Sistemas y Recursos Forestales 2007 16(3), 211-221
ISSN: 1131-7965

# Natural gum and resin bearing species of Ethiopia and their potential applications

W. Tadesse[1]*, G. Desalegn[2] and R. Alia[3]

[1] *Ethiopian Institute of Agricultural Research. Forestry Research Center. P.O. Box 30708. Addis Ababa. Ethiopia*

[2] *Ethiopian Institute of Agricultural Research. Forestry Research Center. Forest Products Utilization Research Programme. P.O. Box 2322. Addis Ababa. Ethiopia*

[3] *Instituto Nacional de Investigación y Tecnología y Alimentaria. Mejora Genética Forestal. Ctra. A Coruña, km 7,5. 28040 Madrid. Spain*

## Abstract

Ethiopia is one of the countries well endowed with various species of *Acacia*, *Boswellia* and *Commiphora* that are known to produce gum arabic, frankincense and myrrh, respectively. Over 60 gum and resin bearing species are found in the country. The total area of oleo-gum resin bearing woodlands cover about 2.9 million ha of land in the country, with over 300,000 metric tons of natural gum production potential. *Boswellia papyrifera* is a chief gum resin producing tree species in Ethiopia. The total area covered by the species is estimated to be more than 1.5 million ha. Frankincense and myrrh are used in medicines, beverages and liqueurs, cosmetics, detergents, creams and perfumery, paints, adhesives and dyes manufacturing. Gum Arabic is used as stabilizing, in food and drink industries; in pharmaceuticals, in printing and textile industries. Despite the enormous socio-economic importance of these natural products, the species are declining at an alarming rate due to degradation resulted from agricultural expansion, overgrazing, fire, poor incense harvesting practices, etc. Therefore, research and development efforts and international collaborations could have strong potentials to the conservation, production and commercialization for the benefits of the local, national as well as the international communities.

**Key words**: *Acacia, Boswellia, Commiphora*, frankincense, gum arabic, myrrh.

## Resumen

### Especies productores de resina y gomas naturales en Etiopía y la aplicación potencial de sus productos

Etiopía es uno de los países que tiene varias especies de de *Acacia, Boswellia* y *Commiphora* que son utilizados para la producción de goma arábiga, resina y mirra respectivamente, y en el país se encuentran más de 60 especies productoras de resinas naturales. El área total cubierto por especies productoras de resinas naturales se estima en 2,9 millones de hectáreas en todo el país, con una producción potencial de 300.000 toneladas métricas. *Boswellia papyrifera* es la especies gran productora de resina en Etiopia. El área total cubierta por esta especie se estima por encima de 1,5 millones de ha. La resina y la mirra se usan en la preparación de medicinas, bebidas y licores, cosméticos, detergentes, cremas y perfumerías, pinturas y adhesivos. La goma arábiga se usa como estabilizador en las industrias alimentarías; y en las industrias farmacéuticas, imprentas y textiles. Aunque las resinas natural tienes enormes importancias socioeconómicas, las especies están disminuyendo alarmantemente debido a las degradaciones por la expansión de agricultura, sobre pastoreo, fuego, mala práctica de resinación etc. Esfuerzos en investigación y desarrollo y colaboraciones internacionales podrían tener fuertes potencias en la conservación, producción y comercialización para el beneficio de las comunidades locales, nacionales e internacionales.

**Palabra clave**: *Acacia, Boswellia, Commiphora,* goma arábiga, mirra, resina.

* Corresponding author: wubalemtw@yahoo.com

Received: 08-07-05; Accepted: 25-10-07.

## Introduction

Ethiopia is located in the Horn of Africa between 3-15° N latitude and 33-48° E longitude. The climatic condition of the country varies with topography, and can be categorized as dry, tropical and temperate rainy climate types, with three sub-divisions each, making a total of nine principal climate types. Temperature varies from as high as 47°C in the Afar depression to as low as 10°C in the highlands. The dryland areas cover 71.5% of the country's total land area (Tamire, 1997). Of the total estimated area of drylands, 25 million ha is covered with woodland and bushland (Tefera *et al*., 2005).

Ethiopia is an agrarian country, and agriculture, including forestry accounts for 54% of the Gross Domestic Product (GDP), employing 85% of the population, accounts for about 90% of exports and supplies over 90% of the raw materials for the agro-industries (CSA, 2000).

Ethiopia also owns a uniquely diverse flora and fauna resources. The flora of Ethiopia comprises about 6,500-7,000 species of higher plants out of which 12% are endemic. The forest resource has significantly and steadily declined both in size (deforestation) and in quality (degradation) to a only about 3.56% (WBISP, 2004). Despite the reduction in size and quality, the actual and potential contributions to the national and local economy from the forest-tree resources of the country are tremendous and versatile.

Natural gums and resins are among dry land resources in Sub-Saharan Africa including Ethiopia that contribute to improved livelihoods of local communities in terms of food security, industrial supply, income generation and foreign exchange earnings. These resources also contribute to the amelioration of the environment. The development of these resources and commodities is key to sustainable management and development of the dry lands, which due to harsh environmental conditions have fewer alternative options.

Africa is the world's leading producer and exporter of gum arabic, frankincense and myrrh. Sudan accounts for 80% of the world's gum arabic production, followed by Senegal, Nigeria, Mauritania, Mali, Ethiopia, Chad, Tanzania and Niger, according to their importance (Seif el Din and Zarroung, 1996). The European Community is by far the biggest regional market for gum arabic. Imports averaged about 28,000 tonnes/year, with a peak of over 32,000 tonnes in 1991 (FAO, 1995).

At the national scale, between 1996 and 2003, Ethiopia exported 16,019 tons of natural gums (gum arabic, frankincense, myrrh and opopanax), which worth 20,473,058 USD. The gums and gum resins sub-sector are playing significant economic role both at the local and national level today in Ethiopia, and their contribution is growing every year (Demel and Mulugeta, 2005).

These species are the source of aromatic gum resins, frankincense and myrrh. They are widely used as raw materials in several industries such as pharmacology, food, beverage, flavouring, liqueurs, cosmetics, detergents, creams and perfumery, paints, adhesive and dye manufacturing, etc. (Mulugeta *et al*., 2003; Getachew and Wubalem, 2004).

Despite the enormous socioeconomic importance of *Acacia, Boswellia* and *Commiphora* species, they are declining at an alarming rate due to degradation due to agricultural expansion, overgrazing, fire, poor incense harvesting practices, shifting cultivation, termite and other infestations (Wubalem *et al*., 2002).

This paper presents a review on natural gum and resin bearing *Acacia, Boswellia* and *Commiphora* species of Ethiopia and their potential applications in different industries and other sectors. The distribution, ecology and production methods are described. Special emphasis is given to *Boswellia papyrifera, Acacia senegal*, *Acacia seyal* and *Commiphora myrrha,* the major gum and resin producing species in the country. Finally, constraints on the gum resin producing species and production sector in Ethiopia are discussed. The over all information provided can be used as an indicator of the rich resource and production potentials and major bottlenecks in the gum resin resources of the country with the implication of the need to plan for integrated studies and collaboration of potential stakeholders on regeneration, management, conservation and economic utilization of the species aspects.

## Socio-economic importance of gum resin products in Ethiopia

The economic importance of plant gums resins, oils and other extracts in the generation of income to the government as a source of valuable foreign currency has been extensively demonstrated in Ethiopia (Table 1).

Employment opportunities have been generated throughout the year by the *Boswellia* products sub-

**Table 1.** Amount of natural gum export from Ethiopia and its value

| Year | Quantity (tons) | Value (USD) |
|---|---|---|
| 1999 | 1,594 | 2,134,389,6 |
| 2000 | 2,079 | 2,807,408,8 |
| 2001 | 2,209 | 2,771,111,9 |
| 2002 | 2,377 | 2,046,930,3 |
| 2003 | 2,720 | 4,128,165,3 |

*Source:* Demel and Mulugeta (2005).

sector include tapping and collection, transportation, processing (cleaning, sorting and grading), marketing of frankincense and guarding of storage facilities (Wubalem *et al.*, 2002). At household level, studies carried out in one region of Ethiopia have shown that the gum resins business provides income about 3 times greater than the contribution of crop farming (Kindeya, 2002; Mulugeta *et al.*, 2003).

The trees are always in lowland areas (malaria-prone) and scattered in very steep and remote slopes, what makes their harvest very hard and difficult. Women carry out the cleaning and grading processes. The commercial product is available in different qualities from dust, siftings, to tears; and they get different prices depending on the quality, size and species origin (the most expensive is gum myrrh with 3.2 USD/kg, while the other gums range between 0.6-1.5 USD/kg) (Vivero, 200).

While large market demand still exist for the export of these products, substantial quantities of gum and resins are also traded in domestic markets and used locally in households and religious institutions. The demand for incense exceeds the supply and the present supply satisfies less than 15% of the domestic demand (Tilahun, 1997; Demel and Mulugeta, 2005).

## Potential application of gum resin products

### Frankincense and myrrh

Frankincense and myrrh are phytotoxically safe raw materials in industries like pharmaceuticals and food industries. They are used in folk medicines, flavoring, beverages and liqueurs, cosmetics, detergents, creams and perfumery, paints, adhesives and dyes manufacturing (Tilahun, 1997; Getachew and Wubalem, 2004).

Both myrrh and frankincense are highly valued for their aromatic fragrances and are common ingredients in incense, perfume and potpourris, soaps, detergents, creams and lotions, and are often included in meditation blends, as it strengthens the psyche and aids in deepening the meditative state (FAO, 1995).

#### *Food and beverages*

Frankincense and myrrh products have wide-ranges of other industrial uses in areas such as food industry, beverages, candies, chewing gums, confectioneries, gelatins, nut products, puddings and canned vegetables (FAO, 1995). Typical applications include: adhesive thickeners, thickeners, stabilizers, flavouring, fixatives and emulsifying agents in food products, clarification in beverages, and release agents for rubber products. In Middle east, particularly in Saudi Arabia, approximately 500 tonnes of Somali type olibanum are imported for chewing gum manufacturing, while similar quantity are also used in these countries for burning at home (FAO, 1995).

#### *Pharmacological uses*

The applications of fragrant oleo-gum resins known as frankincense and myrrh for medicinal values are among man's oldest therapies. The Papyrus Ebers of about 1500 BC is perhaps the oldest list of prescription; in which the priests who supervised funerals, mummification and cremations described the value of both resins in each of these procedures, as well as in the treatment of wounds and skin sores (Michie and Cooper, 1991). Frankincense and myrrh are still widely used therapeutically in regions raging from North Africa to China (Krieglstein *et al*., 2001), and especially in the traditional Ayurvedic medicines of India, Arabia and China as well as in Ethiopia and Somalia (Farah, 1994; Mulugeta *et al*., 2003).

Several folklore claims about natural drugs have continued to be verified on modern scientific grounds. Similarly, both frankincense and myrrh have found modern pharmacological applications for several disease treatments most of them as predicted by the traditional therapies. Particularly, their unique chemical compositions, pharmacological activities and non-toxicity tend to support the safe use of these popular traditional drugs in modern therapies (Michie and Cooper, 1991).

### Gum Arabic

Gum Arabic from *A. senegal* is used as thickening, stabilizing, emulsifying and suspending agent in food and drink industries; as tablet-binding agent and cream- and lotions- suspending and emulsifying agents in pharmaceuticals, as film forming and sizing agent in printing and textile industries (Getachew and Wubalem, 2004). It is also used in ceramics, paints, inks, textiles and adhesives (Chikamai, 1996).

*Food applications*

Gum arabic is mainly used in the confectionery industry, where it is incorporated in a wide range of products. It has a long tradition of use in wine gums, where it produces a clarity that is higher than the clarity obtained with other hydrocolloids. It is also used in chewing gum as a coating agent and as a pigment stabilizer. Due to its stability in acid conditions and its high solubility, gum arabic is well suited for use in citrus and cola flavor oil emulsions. In beer, it is used as a foaming agent and to assist lacing. Gum arabic is used increasingly as a source of soluble fiber in low-calorie and dietetic beverages. Gum arabic is an effective encapsulation agent because of its high water solubility, low viscosity, and emulsification properties and it is used in soups and dessert mixes (Verbeken, 2003).

*Non-food applications*

Gum arabic was once extensively used in the pharmaceutical industry, but it is now replaced by celluloses and modified starches in many applications. It is still used as a suspending agent, emulsifier, adhesive, and binder in tablet and in demulcent syrups (Getachew and Wubalem, 2004). In cosmetics, gum arabic functions as a stabilizer in lotions and protective creams, where it increases viscosity, imparts spreading properties, and provides a protective coating and a smooth feel. It is used as an adhesive agent in blusher and as a foam stabilizer in liquid soaps (Whistler, 1993).

In the textile industry, it is used as a thickening agent in printing pastes for the coloration of knitted cellulose fabrics. Other applications are ink and pigment manufacture, ceramics, and polishes, heat- and shear-sensitivity of the gum (Verbeken, 2003).

## Description, distribution and ecology of gum and resin bearing species and their production aspects

Ethiopia is one of the countries well endowed with various species of *Acacia*, *Boswellia* and *Commiphora* that are known to produce gum arabic, frankincense and myrrh, respectively. Available estimates prompt that the total area of oleo-gum resin bearing woodlands cover about 2.9 million ha of land in the country (Table 2), with over 300,000 metric tons of natural gum production potential (Girmay, 2000). The trees produce resin in the dry season and provide people with meaningful economic activities in a period with few other economic activities (Mulugeta *et al*., 2003).

Over 60 gum and resin bearing species are found in the country (Vollesen, 1989). The most commonly well-known sources of gum and resin species in Ethiopia are described in Table 3.

**Table 2.** Estimated areas covered by natural gum and resin bearing species in the different regions in Ethiopia

| National Regional State | Genus | Estimated area (ha) |
|---|---|---|
| Tigray | *Boswellia, Sterculia, Commiphora & Acacia* | 940,000 |
| Amhara | *Boswellia, Commiphora, Acacia & Sterculia* | 680,000 |
| Oromia | *Boswellia, Acacia, Commiphora & Sterculia* | 430,000 |
| Gambella | *Sterculia, Acacia & Commiphora* | 420,000 |
| Somali | *Boswellia, Acacia & Sterculia* | 150,000 |
| Benshangul-Gumuz | *Boswellia, Acacia & Sterculia* | 100,000 |
| SNNP* | *Boswellia, Acacia & Sterculia* | 70,000 |
| Afar | *Commiphora & Acacia* | 65,000 |
| Total | | 2,855,000 |

* SNNP: Southern Nations, Nationalities and Peoples. *Source:* Girmay (2000).

**Table 3.** List of common gum and resin bearing trees and shrubs in Ethiopia by genus and species

| No. | Genus *Boswellia* | No. | Genus *Commiphora* |
|---|---|---|---|
| 1 | *Boswellia papyrifera* (Del.) Hochst | 1 | *Commiphora myrrha* (Nees) Engl. Syn. C. molmol |
| 2 | *Boswellia microphylla* Chiov | 2 | *Commiphora africana* (A. Rich.) Engl. |
| 3 | *Boswellia neglecta* S. Moore | 3 | *Commiphora habessinica* (Berg) Engl. |
| 4 | *Boswellia ogadensis* Vollesen | 4 | *Commiphora truncata* Engl. |
| 5 | *Boswellia pirrotae* Chiov. | 5 | *Commiphora boranensis* Vollesen |
| 6 | *Boswellia rivae* Engl. | 6 | *Commiphora guidottii* Chiov. |
| | | 7 | *Commiphora schimperi* (Berg) Engl. |
| | **Genus *Acacia*** | 8 | *Commiphora erythraea* (Ehrenb) Engl. |
| 1 | *Acacia Senegal* (L.) willd var. Senegal & var. kerensis | 9 | *Commiphora corrugata* Gillett & Vollesen |
| 2 | *Acacia seyal* Del. var. seyal & var. fistula | 10 | *Commiphora cyclophylla* Chiov. |
| 3 | *Acacia polyacantha* willd. var. *camplacantha* | 11 | *Commiphora hildebrandtii* Engl. (Engl.) |
| 4 | *Acacia sieberiana* DC sieberiana | 12 | *Commiphora odia* Sprague |
| 5 | *Acacia drepanolobium* | 13 | *Commiphora kua* (R. Br. Ex. Royle) Vollesen |
| | | 14 | *Commiphora serrulata* |
| | | 15 | *Commiphora monoica* Vollesen |

*Source:* Vollesen (1989) and Chikamai (1996).

## Genus *Boswellia*

*Boswellia* is one of the 17 genera described in the family *Burseraceae*. The genus is composed of 20 species extending from Ivory Coast to the Horn of Africa and southwards to the northern Madagascar. It is also found in the Middle East as well as India. The center of geographical diversity of the genus is located in the northeast tropical Africa within the dry lowland areas where more than 75 % of its species are endemic (Vollesen, 1989; Azene *et al*., 1993; Farah, 1994; FAO, 1995).

*Boswellia* is an indigenous lowland tree species found in *Acacia-Commiphora* woodlands, wooded grasslands and *Combretum-Terminallia* or broad-leaved deciduous woodlands of Ethiopia. It grows at an altitudinal range of 950-1,800 m, a temperature range of 20-25° C and with rainfall of less than 900 mm per annum. The ecological distribution of the species is confined to lowlands subjected to hot and arid conditions (Vollesen, 1989).

Frankincense (Gum olibalum) is oleo-gum resin obtained from several species of Boswellia trees. Frankincense is produced and exported by few countries. Somalia and Ethiopia are the major producers and exporters (Farah, 1994; FAO, 1995). In India resinous gum obtained from *Boswellia serrata* is also traded as frankincense under the name of «Indian olibanum» (Murthy and Shiva, 1977; Farah, 1994; FAO, 1995).

Three types of frankincense products are recognized in Ethiopia, namely the Tigray, Ogaden and Borena types. The Tigray type is the gum resin obtained from *B. papyrifera* (Table 2 and 3) and the most widely traded frankincense (with over 90% of the natural gum export). This is the type of frankincense produced in the west, north and northwestern parts of Ethiopia. The Ogaden and Borena types represent frankincense produced in the eastern as well as southeastern and southern parts of the country, respectively (Girmay, 2000).

### *Boswellia papyrifera* (Del.) Hochst

*Boswellia papyrifera* is an indigenous tree of Ethiopia that belongs to the family *Burseraceae*. It is a deciduous tree that reaches to the height of 12 m or more at maturity (Fig. 1A). It is widely distributed in Ethiopia, Eritrea, Nigeria, Cameron, Central Africa Republic, Sudan, Chad and North East Uganda (Vollesen, 1989).

In Ethiopia it is found in dry *Acacia-Commiphora* woodland and wooded grassland of western Tigray, Gondar and Shewa regions (Bekele *et al*., 1993), usually dominant on steep rocky slopes, lava flows or sandy valleys, with 950-1,800 m.a.s.l. altitudinal range and temperature of 20-25°C, and rainfall less than 900 mm per year (Vollensen, 1989; Azene *et al.,* 1993, Fitchl and Admasu Adi, 1994),.

Frankincense trees produce leaves with small showers of rain that start in April. The leaves drop sometime in November at the beginning of the dry season. The plant can be propagated from seeds and cuttings (Azene *et al*., 1993; Fitchl and Admassu Adi, 1994).

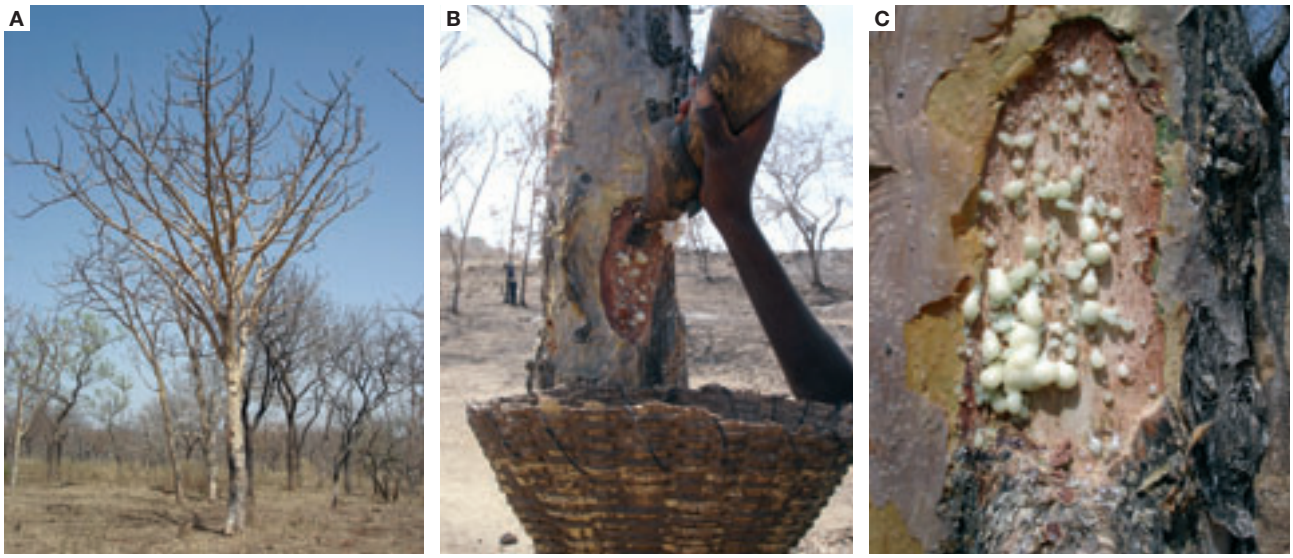


**Figure 1.** Tapping of *B. papyrifera* tree and collection of frankincense. A: *Boswellia trees.* B; Tapping and collection of frankincense from the tree and; C: tapped tree with frankincense exuding.

*B. papyrifera* is a chief gum resin producing tree species in Ethiopia. The total area covered by the species is estimated to be more than 1.5 million carried out in Tigray and Amhara regional states (Table 2).

*B. papyrifera* population in the country is encountered in natural forests. Little or no efforts have been made to domesticate the species. One of the major problems associated with *B. papyrifera* is hampered natural regeneration (Tilahun, 1996; Oqbazghi, 2001; Abeje, 2001), which could be attributed to several factors. For instance, *B. papyrifera* is very sensitive for natural or human interferences and could be damaged easily. The most common factors observed causing damage to the trees, in North Gonder Zone, were windfall, insect attack (unidentified whitish worm), termite, fire, improper tapping, clearing and de-branching by local farmers and trampling and browsing by cattle. Especially, the worm attack was very common (Abeje, 2002).

Hence, at present frankincense production, and even the existence of the species in the country is seriously threatened by accelerated deforestation rate mainly through land clearing for more agricultural land, frequent wildfires and overgrazing.

### *Production, processing and marketing of frankincense*

Harvesting of natural gums, including frankincense, is believed to have a long history. In Ethiopia, harvesting of natural gums is done manually by labor-intensive traditional methods of tapping. One Governmental and several nongovernmental organizations are actively involved in frankincense production and commercialization activities in different regions of the country.

Tapping and collection of frankincense is carried out following a specific pattern around mid-September up to the offset of the dry season, usually June. The technique of tapping usually involves the shaving of a very thin, i.e. 2 mm deep and 4-8 mm wide, external circular layer of the bark starting at 0.5 m from the base of the stem using a hand tool, locally known as 'Mingaf' (Fig. 1B) (Girmay, 2000).

Once the first tapping is done, the second tapping will take place after 30-40 days, and involves a moderate widening of the wound, which will be started during the first tapping. This tapping process will continue for three to four months until the wound has reached 4 cm in width. Usually three such tapping spots are made on each side of the plant, but they could also be four in some cases. Thus, six to eight tapping spots are made as a whole on each plant depending on its size (Girmay, 2000).

After each wounding/incision, the exudate starts to ooze and becomes dry in two to three weeks when it will be ready for collection (Fig. 1C). The wound is renewed immediately while collecting the gum to prevent the hole through which the exudate comes out from drying. The whole process is repeated at intervals of two to three weeks until the onset of the rainy season.

The collection of gum olibanum is normally stopped during the first week of June since the plant starts producing leaves, which enable it to start the process of photosynthesis. During this period (October-June), one taper collects, on the average, 10-12 quintals, and an average of 500 g of frankincense is obtained from individual trees per tree per season (Girmay, 2000).

The harvested resin is first stored in temporary stores established at the harvesting sites. Later on, it is transported to permanent stores for processing. Processing of the resin involves the manual cleaning, sorting and grading of the raw product, which is usually done by women. Accordingly, the collected gum is sorted into five grades on the bases of size, colour and brightness (Girmay, 2000). The final products are, then, sold in international markets (the first 2 quality grades) and the least qualities for domestic use, which will be used in coffee ceremonies, churches, etc.

Other uses of *B. papyrifera*

Ecologically the species is important since it can grow in areas where other trees fail to grow. The wood of *Boswellia* is used for poles and timber and for industrial manufacturing of matchboxes, boards and plywood. The leaves provide dry-season fodder, and the flowers are a good source of nectar for bees. Leaves, bark, and roots are also used in traditional medicines. The species is recommended for economic development and desertification control (Stiles, 1988).

## Genus *Acacia*

Gum arabic is the oldest and best known of all natural gums. The genus *Acacia* is the second largest within the Leguminosae family (sub family Mimosoidae) and contains at least 1,000 species. A total of 17 *Acacia* species were identified as producing gum in Africa which are collected by local communities-either for export and/or domestic use (Chikamai, 1996). The gum arabic-yielding *Acacia* species grow in semi-arid areas and the vast majority of gum arabic, which enters international trade, originates in the so-called gum belt of Sub-Saharan Africa, extending from the northern parts of West Africa eastwards to Sudan and Ethiopia. A little gum is of Indian origin (Chikamai, 1996).

Gum arabic from Sudan (from the Kordofan region) is the highest quality and sets the standard by which other «gum arabics» are judged (Verbeken *et al*., 2003). Gum arabic samples collected from *A. senegal* from North-Western Ethiopia (Metema), showed a nearly identical chemical properties with a gum sample of the same species obtained from Kordofan (Ermias, 2003).

Commercial *Acacia* gum from Ethiopia is produced from different botanical sources. Gum arabic of commerce is produced from *A. senegal, A. seyal* and *A. polyacantha*, which are only distinguished on the basis of different production areas (Chikamai, 1996; Getachew and Wubalem, 2004).

Annual production of gum Arabic from *A. senegal* and *A. seyal* species in the period 1988-1999 was 300-400 tone. *A. senegal* comprises about 70 % and *A. seyal* about 15–25% of the species that contribute up to 95% of the total gum entering international trade. The remaining 5% which is relatively low quality gum is contributed mainly by *A. Polyacantha* and *A. drepanolobium* (Getachew and Wubalem, 2004).

*Acacia senegal* (L.) Willd (1806)

*Acacia senegal* is a deciduous shrub or tree up to 15 m high, crown variable, flat to rounded; bark yellowish-brown to purplish black, rough or smooth, scaly (Dagnew, 2006). *A. senegal* var. senegal is found in Mauritania, Senegal, Gambia, Ghana, Burkina Faso, Cote d'Ivoire, Mali, Niger, Nigeria, Cameroon, Zaire, Central African Republic, Rwanda, Chad, Sudan, Ethiopia, Somalia, Uganda, Kenya, Tanzania, Mozambique, Oman, Pakistan, and India (Azene *et al*., 1993).

*A. senegal* thrives on dry rocky hills, in low-lying dry savannas. This hardy species survives many adverse conditions, and seems to be favoured by low rainfall and absence of frost. It ranges from Warm Temperate Thorn through Tropical Thorn to Tropical Dry Forest Life Zones. It is very drought resistant. It grows on sites with annual rainfall mainly between 300-400 mm, and 5-11 month dry periods. It tolerates high daily temperatures (mean maximum temperatures of up to 45°C or more), dry wind, and sandstorms. *A. senegal* prefers coarse-textured soils such as fossil dunes, but it will also grow on slightly loamy sands and skeletal soils such as Lithosols (Cossalter, 1991).

Common in dry and moist lowland agroclimatic zones of the Afar plain, Western Wello, Shewa, Bale, and Hararge. It tolerates high daily temperature and a

long dry season. Widespread in dry scrub, wooded grassland, 600-1,700 m (Azene *et al.*, 1993). Available from sea level to 1,000 m in altitude with annual rainfall of 250 mm (Thirakul, 1993).

*A. senegal* is propagated well in seeds. Seed should be harvested before pods have dried for easy collection and to avoid insect attack. Another method of propagating is by shoot cuttings and coppicing (Dagnew, 2006).

Due to the increased demand of Gum arabic in international market and the socioeconomic importance of *A. senegal* in the country reforestation of the species is being carried out since the last few years by governmental and non governmental organizations of Amhara and Tigray regional states. Nevertheless, the existing gum production in the country is carried out in natural forests.

*Production, processing and marketing of gum arabic*

Gum exudes from cracks in the bark of wild trees. In Africa, it is regularly tapped from trees, which are about six years old by making narrow transverse incisions in the bark of stems and branches in February and March. In about a month, tears of gum form on the surface and are gathered. Trees begin to bear between 4-18 years of age and are said to yield only when they are in an unhealthy state owing to poor soil, lack of moisture or damage. In Sudan and Nigeria, virtually all gum from *A. senegal* is obtained by tapping the trees; there is very little natural exudation. *A. senegal* does produce gum naturally and all of the gum which is collected comes from harvesting natural exudates (Dagnew, 2006). In Ethiopia gum arabic is collected both from naturally oozing (Southern part of Ethiopia) and by tapping (Northern part).

Yields of gum arabic from individual trees are very variable. A figure of 250 g of gum per tree per season is often cited as an average yield from individual trees (Dagnew, 2006).

Other uses of *A. senegal*

*A. senegal* is an amazing tree. It grows where almost nothing else will survive, enriches the soil with nitrogen, and provides nutritious fodder and gum arabic. Specifically, gum arabic is an extraordinary harvest from *A. senegal* which can bring security to the fragile existence of people in the arid lands who depend on livestock or dry-land farming (Holmes, 1997). Wood from *A. senegal* is an excellent slow-burning fuelwood giving intense heat and little smoke, it also used for charcoal making (FAO, 1995). *A. senegal* is important for desertification control through sand dune stabilization and wind breaks. It has role in agricultural systems by restoring soil fertility (Cossalter, 1991). It is an important tree for agroforestry systems in arid and semi-arid areas of Sudan and Western Ethiopia (Asfaw and Thulin, 1989). It is browsed by livestock, especially goats and camels, and is reputed to fatten livestock and enrich milk. It is a good source of bee food (Dagnew, 2006).

*Acacia seyal* Del. (1813)

Deciduous and indigenous tree of the savanna woodland and the semi-arid lowland forest, in between 700-1,800 m of altitude, commonly found gregariously on the rock hillsides or in the drier parts of *Acacia* thicket (Thirakul, 1993). It is flat topped or umbrella shaped small to medium sized tree to 17 m and available to 1,200-2,100 (Vollesen, 1989), 2,100 m in Welo, Gonder, Gojam, Shewa, Arsi, Hararige, Illubabor, Kefa, Sidamo, Tigray, and other areas of Ethiopia where the area is seasonally flooded black-cotton soil in river valleys and wooded grassland of dry and moist medium/ woyena dega agroclimatic zones (Azene *et al.*, 1993; MacLachlan, 2002). Easily recognized from a distance by its typical shining greenish white or greyish white bark (Thirakul, 1993; MacLachlan, 2002). Having strong white thorns to 8 cm long (MacLachlan, 2002). The milky white pairs of prickles, straight bifurcated, are mostly swollen at the base (Thirakul, 1993).

## Genus *Commiphora*

Trees or shrubs; branches often terminating in spines; outer bark often papery and peeling, inner bark usually greenish with resinous usually aromatic sap, wood with milky latex (Vollesen, 1989).

The Genus *Commiphora* includes 150-200 species widespread in the drier parts of tropical Africa and Madagascar. The genus is a very conspicuous and a dominant element in the dry bush lands of Northeast Africa, and a large number of species are endemic in this area (Vollesen, 1989).

Fifty-two species of *Commiphora* are known to exist in Ethiopia, and 14 (25%) of the species are endemic. However, very few are used to collect resin (Table 2). The chief *Commiphora* gum of highly economic importance is myrrh, produced by *Commiphora myrrha* (Nees) Engl. (1883), *(*synonum *C. molmol)*. This is an important commodity of commerce in Southern and South Eastern Ethiopia (Vollesen, 1989).

*Commiphora myrrha* (Nees) Engl

*C. myrrha* is an indigenous tree or shrub to 4 m; bark silvery or whitish to bluish grey, peeling in small to large papery flakes, sometimes reticulately fissured on old trunks; all parts glabrous (Vollesen, 1989). Grows in *Acacia-Commiphora* woodland and bush land on sandy to loamy soil overlying limestone or granite, rocky lava hills; 250-1,300. Available in the regions: Afar, Sidamo, Bale, Hararge and out of Ethiopia in Somalia; North East Kenya and Arabia (Vollesen, 1989). The resin of this species is the raw material of the renowned myrrh. Myrrh is also collected from other species of *Commmiphora* such as *C. africana*, *C. erythraea, C. gileadensis*, etc. but the best quality is from *C. myrrha* (Azene *et al*., 1993; MacLachlan, 2002).

Gum production is carried out by collecting exudates from trees in natural stands by random picking from naturally and/or accidentally exuding trees by peasants and pastoralists. Gum collection is considered secondary as it is carried out while executing other activities perceived to be more important namely firewood collection and livestock.

## Constraints in development, conservation and utilization of gum resin bearing tree species

Remoteness as well as the rugged and undulating topography of the habitat where the gum producing species grow, lack of access roads and infrastructure/ facilities such as residential quarters and inadequacy of transport facilities to the potential production areas have made mobilization of labour force, equipment and supplies, collection and transportation of harvested natural gums very difficult.

Deforestation, over grazing, resettlement and other land use change impacts. Clearing of the woodlands for farming and settlement, deliberately set fire, and harvesting for fuelwood are becoming the major threat to the future of the oleo-gum resin producing vegetations as well as the biological resources associated with them (Abeje, 2002). For instance, in Tigray region more than 177,000 ha of *Bosswellia* forest is reported to be destroyed in the last 20 years (Kindeya, 2003). Similar reports exist for Gonder (Abeje, 2002), and the Somali region (Mulugeta *et al*., 2003). Besides, assessments of *B. papyrifera* population in the north and northwestern parts of Ethiopia showed lack of natural regeneration leading to the listing of the species as one of the endangered species in Ethiopia (Kindeya, 2003).

Inappropriate tapping of *B. papyrifera*. It was observed that the proportion of trees damaged/attacked by the unidentified worm was higher in tapped trees than those with untapped trees (Abeje, 2002) indicating that tapping exposes the tree for attack by pests and other damages. Also the worm attack has been found to hamper regeneration by inducing the production of non-viable seeds (Oqbazghi, 2001; Abeje, 2002). According to Farah (1994), the over all damages done to frankincense trees owing to improper tapping is tremendous, and perhaps over 50% of the frankincense trees subject to tapping are often damaged. Together with other damages such as overgrazing, fire and clearance for agriculture, improper tapping is causing a widespread damage including hampering natural regenerations. The deterioration of the woodland vegetation stocks in the drylands is the principal root cause for advancing desertification in the region (Mulugeta and Demel, 2004).

Lack of trained manpower in tapping natural gums, interference from human and domestic animals have, in one way or another, contributed to the low volume and quality of products (Girmay, 2002).

No attempts have been made to domesticate the species as yet in spite of the fact that seeds, at least of *B. papyrifera*, can germinate readily since they have low or no dormancy (Tilahun and Legesse, 1999) and vegetative propagation seems relatively easy.

Lack of devising mechanisms to promote the countries' potential for value addition and industrialization of gum resin products.

The inadequate/insufficient research undertaking is one of the gaps owing to the prevalent shortage of trained researchers, physical facilities and budget in the Forestry Research System as a whole, which, in turn, is a direct reflection of the low profile and priority given to the Forestry Sub-sector in the country.

## Conclusions and recommendations

Ethiopia has a large, as yet, properly unexploited potential to produce natural gums resin resources in its different regions. However, the vegetation resources are dwindling very rapidly due to the continuous pressure from deforestation also associated with agricultural expansion, over-grazing, insect attack, improper tapping, etc., as well as insufficient/inadequate research undertakings, absence of strategies and action plans for the development, sustainable utilization and conservation of these resources.

Given the significant socio-economic, cultural and ecological importance of natural gum bearing species in general and species of *B. papyrifera* in particular, viable strategies and realistic action plans for research, development, sustainable utilization and conservation of the species and their habitats have to be developed and implemented in the country before it is too late.

Therefore, research and development efforts and international collaborations could have strong potentials to the conservation, production and commercialization of these vast and untapped renewable natural resources for the benefits of the local, national as well the international communities. The country is collecting and exporting only the crude gum resin resources and again imports with foreign currencies their various final products from developed countries. Therefore, devising mechanisms to promote the countrie's potential for value addition and industrialization of gum resin products should be one of the priority collaboration line in the near future.

## Acknowledgments

The authors would like to thank the two anonymous reviewers for their valuable and constructive comments on the manuscript.

## References

ABEJE E., 2002. Regeneration status, soil seed banks and socio-economic importance of *B. papyrifera* in two woredas of North Gonder Zone, Northern Ethiopia. MSc Thesis, Swedish Universit of Agricultural Sciences, Skinnskatteberg, Sweden.

ASFAW H., THULIN M., 1989. Mimosoideae. In: Flora of Ethiopia, pittosporaceae to araliaceae (Hedberg I., Edwards S., eds). The National Herbarium, Biology Department, Addis Ababa University and The Department of Systematic Botany, Uppsala University, Vol. 3. Addis Ababa. pp 71-96.

AZENE B., BIRNIE A., TENGNAS B., 1993. Useful trees and shrubs for Ethiopia. Identification, propagation and management for agricultural and pastoral communities. Regional Soil Conservation Unit, SIDA, Nairobi.

CHIKAMAI B., 1996. A review of production, markets and quality control of Gum Arabic in Africa. Technical cooperation programme. FAO of the United Nations. Project No. TCP/RAF/4557. Rome.

COSSALTER C., 1991. *Acacia senegal:* gum tree with promise for agroforestry. NFT Highlights, No. 91-02.

CSA (Central Statistical Authority), 1999. Statistical Abstract (1998). Addis Ababa.

DAGNEW Y., 2006. Population status of *Acacia senegal* (Linne) willdenow and its gum quality in the central rift valley of Ethiopia. MSc Thesis. The Department Of Farm Forestry, Wondo Genet College Of Forestry, School of Graduate Studies Awassa University, Awassa, Ethiopia. 77 pp.

DEMEL T., MULUGETA L., 2005. Role of forestry in poverty alleviation in Ethiopia. Debub University, Wondo Genet College of Forestry, Shashamane, Ethiopia. 70 pp. Unpublished.

ERMIAS D., 2003. Report of analysis of gum arabic from Metama. Addis Ababa University, Ethiopia (Unpublished report).

F.A.O. (Food and Agricultural Organization), 1995. Flavours and fragrances of plant Origin. Non-wood forest products 1, Rome.

FARAH A.Y., 1994. The milk of the *Boswellia* forests: frankincense production among the pastoral somali. Uppsala University, Uppsala.

GIRMAY F., 2000. The status of gum arabic and resins in Ethiopia. Report of the Meeting of the Network for Natural Gum and Resins in Africa (NGARA) 29th-31st May, Nairobi, Kenya. pp. 14-22.

GETACHEW D., WUBALEM T., 2004. Socio-economic importance and resource potential of Non-Timber Forest Products of Ethiopia. Proceedings on conservation of genetic resources of Non Timber Forest Products (NTFPs) in Ethiopia. EARO-IPGRI, 5-6 April 2004, Addis Ababa, Ethiopia. pp. 13-36.

HOLMES I., 1997. Gum Arabic – Life in a saturated market. In: Conservation, management and utilization of plant gums, resins and essential oils (Mugah J.O., Chikamai B.N., Mbiru S.S., Casadei E., eds). Proceedings of a Regional Conference for Africa Held in Nairobi, Kenya, 6-10 October 1997. Nairobi.

KINDEYA G., BART M., MITKU H., MITLOEHNER R., 2002. *Boswellia papyrifera* (Del). Hochst: a tropical key species in northern Ethiopia. Conference on International Agricultural Research for Development. October 9-11, Deutscher tropentag. Germany.

KRIEGLSTEIN F.C., ANTHONI K., RIJCKEN E.J.M., LAUKÖTTER M., SPIEGEL H.-U. BODEN S.E., 2001. Acetyl-11-keto-β-boswellic acid, a constituent of a herbal

medicine from *Boswellia serrata* resin, attenuates experimental ileitis. Nant glioma: induction of apoptosis but no modulation of drug sensitivity. Br J Cancer 80, 756-765.

MACLACHLAN M., GETANEH E., TAFERE F., 2002. Manaual of highland Ethiopian trees and shrubs. Revised and expanded. English and Amharic version. Prepared for development agents of «dega» areas in Regon 3. SIM Forestry study project. Injibara, Awi zone, Region 3, Ethiopia. 465 pp.

MICHIE C.A., COOPER E., 1991. Frankincense and myrrh as remedies in childern. J R Soc Med 84(10), 602-605.

MULUGETA L., TAREKEGN A., OLSSON M., 2003. Gum and resin resources from some *Acacia*, *Boswellia* and *Commiphora* species and their economic contribution in Liban, Southeastern Ethiopia. Journal of Arid Environments 55, 465-482.

MURTHY T.K., SHIVA M.P., 1977. Salai guggul from *Boswellia serrata* Roxb- Its exploitation and utilization. Indian Forester. pp. 466-474.

OQBAZGHI W., 2001. The distribution and regeneration of *Boswellia papyrifera* (Del.) Hochst. in Eritrea. PhD Dissertation, Wageningen University, Wageningen.

SEIF EL DIN A.G., ZARROUG M., 1996. Production and commercialization of gum arabic in Sudan. Warm Seas Shipping and Trading Co. Ltd., P.O. Box 44731, Khartoum, Sudan and 23 Wellington Rd, London NW8 9SL, England.

STILES D., 1988. Arid land plants for economic development and desertification control. Desertification Control Bulletin 17, 18-21.

TAMIRE H., 1997. Desertification in Ethiopian Highlands. RALA Report No. 200. Norwegian Church AID, Addis Ababa, Ethiopia. 162 pp.

TEFERA M., DEMEL T., HULTEN H., YONAS Y., 2005. The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and Northern Ethiopia. Journal of Arid Environments, Vol. 60, pp. 259-281.

TILAHUN G., 1997. *Boswellia papyrifera* (Del.) Hochst. from Western Tigray. Opportunities, constraints and seed germination responses. MSc Thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

TILAHUN G., LEGESSE N., 1999. The effect of different pre sowing seed treatments on the germination of *Boswellia papyrifera*, a key dry land tree. Ethiopian Journal of Natural Resources 1, 57-75.

VERBEKEN D., DIERCKX S., DEWETTINCK K., 2003. Exudate gums: occurrence, production, and applications. Appllied Microbiology Biotechnology 63, 10-21.

VIVERO J.L.P., 2001. The role of forest resources in non-farm activities and their importance for rural livelihood diversification in Ethiopia: «Imperative problems associated with forestry in Ethiopia». Paper presented at the XI$^{th}$ Annual Conference of the Biological Society of Ethiopia. Addis Ababa University, February 1-3, 2001.

VOLLESEN K., 1989. Burseraceae. In: Hedberg I., Edwards S., eds. Flora of Ethiopia, Volume 3. National Herbarium, Addis Abeba University, Addis Abeba and Uppsala University, Uppsala. pp. 442-478.

VOLLESEN K., 1995. Flora of Ethiopia and Eritrea. In: Hedberg I., Edwards S., eds. Volume 2, aprt 2. National Herbarium, Addis Abeba University, Addis Abeba and Uppsala University, Uppsala.

WHISTLER R.L., 1993. Exudates gums. In: Whistler R.L., Bemiller J.N., eds. Industrial gums: polysaccharides and their derivatives. Academic Press, San Diego. pp. 318-337.

WBISP (Woody Biomass Inventory and Strategic Plan project), 2004. Forest Resources of Ethiopia, Addis Abeba.

WUBALEM T., DEMEL T., MULUGETA L., GIRMAY F., 2002. Boswellia country report for Ethiopia. In: Chikamai B., ed. Review and synthesis on the state of knowledge of *Boswellia* species and commercialization of frankincense in the dry land of Eastern Africa. FAO/EU/FORNESSA Publication. pp. 11-33.