Determination of high yielder point and wound recovery to optimize frankincense yield from *Boswellia papyrifera* trees in the lowland of North Gondar Zone

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Abstract
Boswellia papyrifera (Del.) Hochst is threatened as the result of several interrelated factors and among these factors exploitation system is considered to be the major cause for the decline of the species. Boswellia trees are used to be tapped every year in the dry season and heavy tapping is observed to damage the cambium and curtail the life span of the trees due to slow wound healing. Research intervention in the area of tapping technique helps to alleviate problems of damaging trees during tapping and to enhance incense production. This study was conducted at Metema Woreda Lemelem Terara kebele North Gondar Zone from 2002 to 2003 E.C. The objectives of this study were to investigate: i) the effect of tapping height and tree size on wound recovery, and ii) the effect of tapping height and tree size on frankincense yield. Trees were selected for the experiment based on different diameter classes. To keep the homogeneity among the experimental trees, forty five sample trees with similar tapping history were selected using stratified sampling techniques and then three diameter classes of 10-15 cm, 16-20 cm and 21-25 cm were randomly selected accordingly. For each diameter class, 15 trees were taken and labeled. Then, finally, these trees were allocated to three different tapping height categories (n = 5 per tapping height categories) i.e. tapped at 0.5m, 1m and 1.5m. Following the traditional tapping practices, each tree category were tapped in the east and west direction. Factorial RCBD designs with three level of diameter size and three level of tapping height were used. The result of the wound recovery study showed that among the treatments height showed significant difference. In this study those tapped tree at higher diameter (16-20 cm) of tapping height 0.5 m yield higher wound recovery and trees tapped at lower diameter (10-15 cm) of tapping height 1.5 m exhibited lower wound recovery. The frankincense yield collected from the tapped *B. papyrifera* trees had shown significance difference between treatments of height, diameter and year. The result revealed that trees tapped at higher diameter (21-25 cm) of tapping height of 1 m had bring higher frankincense yield whereas trees tapped at lower diameter (10-15 cm) of tapping height 1.5 m has scored the lowest frankincense yield. Therefore, when tapping is planned to be carried out, it needs to consider tapping height and the tree diameter (DBH) since these are found to be the major factors that determine the frankincense yield and the recovery of the wound.

Key words: *Boswellia papyrifera*, DBH, frankincense, tapping, wound, yield.

Introduction

The dry land woodlands of Ethiopia are endowed with diverse tree species that are known for their valuable Non-Timber Forest Products (NTFPs) of local, national and international significance. One of the well- known species in this regard is *Boswellia papyrifera* (Del.) Hochst. The species is a deciduous multipurpose tree with the potential for economic development and desertification control (Lemenih and Teketay, 2003a, 2004). It is found in the *Combretum–Terminalia-Acacia-Commiphora* (broad-leaved) deciduous woodland and wooded grassland dominant on steep rocky slopes, lava flows or sandy valleys, within the altitudinal range of 950–1800 m altitude (Vollesen, 1989; Azene Bekele *et al*., 1993; Friis 1996; Eshete *et al*., 2005; NBSAP, 2005; Lovett and Ogbazghi *et al*., 2006; Tadesse *et al*., 2007; Abiyu *et al.*, 2010). Frankincense is a gum resin tapped from several species of the genus *Boswellia*, is composed of about 20 species extending from Ivory Coast to India and south to north-eastern Tanzania and Madagascar but most numerous in north-eastern tropical Africa. The resin from *B.papyrifera* (Del) Hochst., Frankincense, is traded at the local and international markets for thousands of years. These products of nature have well established uses in several multibillion dollar and multinational industries such as food, pharmacology, cosmetics, perfumery, beverage (flavours, soft drinks, liquor, and brewery), paints, adhesives, inks and various other industries, thus have large international demands. These products have also wide local uses such as food supplements, ritual/religious applications, folk medicines, and others (Lemenih and Teketay, 2003a, b and 2004).

Besides the direct financial contribution to the local and the national economy, gums and gum resins producing trees and shrubs have considerable ecological role in the dry land ecosystems. *B.papyrifera* is also considered as a valuable species that thrives successfully under the conditions where soil and climate do not offer other opportunities, thus, allowing marginal dry lands to be productively and economically utilized. This behavior of successful establishment and growth of the species under harsh climatic and soil conditions make it one of the best candidates to fight desertification, rehabilitate degraded dry lands and allow adaptation of communities in dry lands to possible climate change (Lemenih and Teketay, 2004). It is also found to be highly suitable for future reforestation establishments or restoration efforts in moisture deficit arid and semi-arid areas (Kindeya *et al*., 2005). Therefore, tree based utilization of dry land ecosystems will assist communities living there to adapt to possible climate change well than, for instance, crop farming (Adam, 2003; Mulugeta *et al.*, 2003a).

Despite its long history in commercial market, studies on the resin system and on factors that determine resin production are scarce. In recent years, these species in Ethiopia particularly in the Amhara region have been facing several challenges in which it is used to be cleared for cropland expansion, overgrazing, intensive tapping and increased frequency of forest fire. At present almost all of the gum-resin resources are collected from the wild and untended plants by the surrounding community, who use crude and haphazard method of incising the main stem by axes. Owing to lack of adequate scientific techniques of tapping and collection procedures, it has become difficult to optimize the utilization and maintain a good quality standard of this indigenous natural product. Trees are tapped every year in the dry season and intensive tapping could injure the cambium and curtails the life span of the tree on account of poor wound-healing. Due to this exploitation the potential range of forest communities with Boswellia is greatly reduced and is classified as an endangered species (NCSS, 1993; Kindeya *et al*., 2002). Thus, research efforts with respect to this species could contribute greatly to the production as well as economic and ecological utilization of these vast untapped resources for the benefits of the local, national as well as international communities. No doubt that research supports in the areas of tapping height and wound recovery for enhancement of production is very crucial. Therefore, the present study aims at investigating new tapping height and diameter class combination for optimum frankincense yield collection and wound recovery from *B.papyrifera* trees species under the case of North Gondar, Amhara National Regional State, Ethiopia.

Material and methods

Site description

Geographically Metema is located at 12°33.58'-12°41.53'N, 36°04.12'-36°18.84E at about 900km northwest of Addis Ababa and Lemlem Terara is situated at about 205 km west of Gondar town, between 36°17'-36 °48'E and 12° 39'-12° 45' N (Figure 1). It is one of the west most woredas of the Amhara Regional State. According to this estimate, the total population of the woreda is 91,216 people. Out of the total, 3918 are rural and 1497 are urban women households.

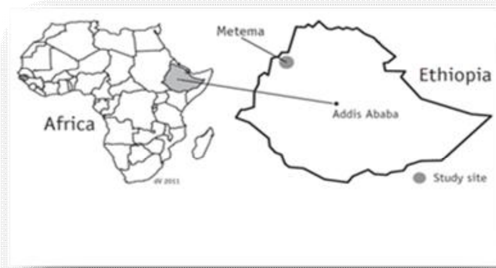

Figure 1. The location of the study site of Metema North Gondar zone of Amhara Regional state, Ethiopia (Tefera Mengistu, 2011 and Abeje Eshete, 2011).

The altitude of Metema ranges from 810 to 990 m.a.s.l. The annual rain fall ranges from 870-1390mm (between 1988 and 2007) with mean annual rain fall of 965mm and has a unimodal rainfall. The rainy season (>100 mm/month) lasts for 4 months from June till September. (Figure 2). The diurnal minimum and maximum temperature per month are 19.6 and 35.7°C respectively. Daily temperature becomes very high during the months of March to May, where it may get to as high as 43 °C (Abeje Eshete, 2011).

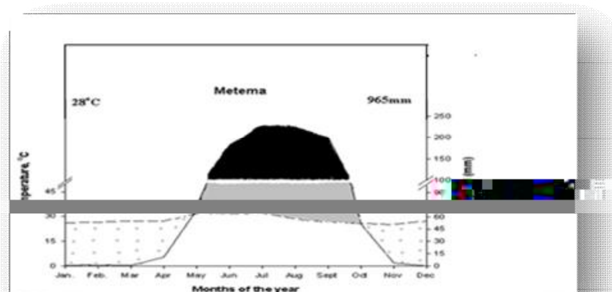

Figure 2. Climate variation over the year for the site taken from Gendewuha meteorological station(~ 25km away from the study plots) for the period from 1988 to 2007.

Note: Monthly rainfall (mm month^{-1}) is indicated by the solid line, mean diurnal maximum temperature per month (°C) by the dotted line, and mean diurnal minimum temperature per month by the dashed line. The annual rain fall ranged from 870 to 1390 mm (Abeje Eshete, 2011).

Nearly all of the land in the woreda is in the lowlands except some mountain tops which fall outside. The soils in the area are predominantly black and some are soils with vertic properties (Emiru Birhane.2011).The natural vegetation is categorized as *Combretum –Terminalia* woodland (NBSAP, 2005) is predominantly composed of different *Acacia spps, Balanites aegyptica, Boswellia papyrifera, Combretum spp, Stereospermum kunthianum and Terminalia brownie* (Abeje Eshete, 2011). Three major rivers namely Shinfa, Guang and Genda wuha drain through the woreda.

Methodology

The study was conducted in Metema Woreda, North Gondar, Ethiopia in very high population of *B.papyrfera* dominated stand at Lemlem Terrara kebele with 850 m m a.s.l. elevation. The experiment was conducted for two production season 2010-2011 and 11 round of frankincense trees tapping were under taken. Trees were selected for the experiment by considering different diameter classes. To keep homogeneity among the experimental trees, trees with similar tapping history were selected using stratified sampling techniques and then trees having three diameter classes of 10-15 cm, 16-20 cm and 21-25 cm were randomly selected. For each diameter class, 15 trees were taken and labeled. These trees then allocated to three different tapping height categories of 0.5 m, 1m and 1.5 m (Table 1).

Following the traditional/local tapping practices each tree category were tapped in the east and west direction. Then the frankincense yield and wound recovery data obtained from each trees was collected and analyzed. Factorial RCBD design with five replications was used (three level of diameter size and three level of tapping height).The tapping materials used to conduct the experiment was Mingaf, plastic bags for collecting the frankincense, sensitive balance for weighing the collected frankincense, diameter caliper for measuring the tree diameter, meter and graduated ruler to determine the tapping height category.

Table1. The number of trees tapped in each tapping height and diameter class.

Tapping height (m)	Tapping DBH (cm)	Number of trees
0.5	10-15	5
	16-20	5
	21-25	5
1	10-15	5
	16-20	5
	21-25	5
1.5	10-15	5
	16-20	5
	21-25	5

DBH = Diameter at breast height.

Data collection and analysis

The frankincense data from tapping was collected from the 45 selected sample trees for each tapping height category i.e. 0.5 m, 1 m, 1.5 m from the month September up to end of May for two productions season. The first frankincense collection round started at the second tapping round. Frankincense production per tree was determined by weighing the freshly harvested frankincense directly after collection using digital balance (0.01 g precision). Wound recovery data were collected after collecting the frankincense yield and this was usually done at the end of the rainy season (i.e. September). The data was obtained by observing the different features observed on the bark of the tapped tree and this was usually done on the tapping spot and we had tried to classify in to four size classification (0-25%, 25-50%, 50-75%, 75-10%). General Linear Model (GLM) procedures of SAS(9.0) software for data analysis was used and further to see the significant difference between treatments mean the data was exposed to LSD mean separation techniques. Data were transformed to natural logarithm to meet the assumption of normal distribution.

Results and discussion

Effect of tapping height and tree size (diameter) on wound recovery

All year round tapping were undertaken on the selected forty five sampled trees and finally before the beginning of the next tapping season wound recovery data from each tapped tree at the first year were collected for two consecutive years. Results showed that tapping height had significant effect on wond recovery (Table 2). However, tree diameter and the interaction between height and diameter did not have significant effect on wound recovery (Table 2). Trees with in the 10-15 cm diameter class and tapped at 1.5 m height and trees with in the 16-20 cm diameter class and tapped at 0.5 m height exhibited the lowest and highest wound recovery percentage, respectively which ranges from 30.5%/tree/year to 50.63%/tree/year (Table 3). This implies that bigger trees tapped at lower tapping height would have faster wound recovery than smaller trees tapped at higher tapping height.

Table 2. ANOVA for the effect of tapping height and tree diameter on wound recovery.

Source	df	Mean Square	F Value	Pr>F
Year	1	1376.833746	11.03	0.0014
Height	2	666.825466	5.34	0.0068
Diameter	2	230.321621	1.85	0.1650
Height*Diameter	4	143.236046	1.15	0.3407

Effect of tapping hieght and tree size (diameter) on frankincense yield production

The effect of tapping height and tree diameter on frankincense yield was also assessed. Results showed that there were significant differences in frankincense yield between tapping height and tapping diameter (Table 4).

Table 3. Effect of tapping height and tree diameter on wound recovery.

Height (m)	Diameter (cm)	Wound Recovery (%)	Std Dev
0.5	10-15	39.50[c]	11.89
0.5	16-20	50.63[a]	10.50
0.5	21-25	43.00[c]	14.94
1	10-15	41.00[c]	13.29
1	16-20	38.89[c]	13.87
1	21-25	46.00[a]	13.29
1.5	10-15	30.50[b]	5.99
1.5	16-20	36.11[b]	9.93
1.5	21-25	38.33[c]	10.31

Means with the same letter are not significantly different at $P<0.05$.

Table 4. ANOVA for the effect of tapping height and diameter on frankincense yield.

Source	df	Mean Square	F Value	Pr>F
Year	1	59865.1671	5.51	0.0216
Height	2	45128.7328	4.15	0.0195
Diameter	2	68730.1816	6.32	0.0029
Height*Diameter	4	2429.8700	0.22	0.9245

Trees with in the 21-25 cm diameter and tapped at 1 m height and trees with in the 10-15 cm diameter and tapped at 1.5 m height gave the highest and lowest frankincense yields, respectively (Table 5). The mean frankincense production potential for each tapping height category and diameter class anges from 39.72 g/tree/year to 204.28 g/tree/year.

Table 5. Effect of tapping height and tree diameter on frankincense yield.

Height (m)	Diameter (cm)	Yield (g/tree/year)	Std Dev
0.5	10-15	98.82[c]	67.97
0.5	16-20	117.46[c]	82.05
0.5	21-25	197.15[a]	177.52
1	10-15	131.92[c]	121.60
1	16-20	172.47[c]	114.60
1	21-25	204.28[a]	132.13
1.5	10-15	39.72[b]	19.09
1.5	16-20	76.53[b]	78.89
1.5	21-25	152.17[c]	80.98

Means with the same letter are not significantly different at $P<0.05$.

Discussion

Tapping height and diameter size on wound recovery

In this study we evaluated the effect of tapping height and tree size (DBH) on wound recovery and frankincense yield. We hypothesized that higher wound recovery can be obtained from each higher tapping height and tree size (DBH). Accordingly, we observed that wound recovery differed between tapped trees with different diameter size and the three tapping height category. In which bigger tree size tapped at lower height of 0.5 m had higher wound recovery than that of smaller trees. Similarly, *B.papyrifera* trees tapped at higher tapping height (1.5 m) had the lowest wound recovery at any diameter size. Abeje (2002) determine the optimal DBH for tapping *in B.papyrifera* to be 10-12 cm and according to his study trees with less than 12 cm DBH may not be able to recover from their wound after tapping. The higher wound recovery result from the bigger trees can be justified as bigger tree practice higher resources acquisition capacities which intern depends on the crown size and leaf areas of trees (Abeje, 2011). According to Tefera (2011), bigger trees had more starch storing capacity than smaller tree in which attributed to attain higher wound recovery in larger trees and this also results in smaller trees suffer sooner from carbon starvation by tapping. For example, Murphy and Shiva (1977) indicated that the original thickness of *B.serrata Roxb* was regained from wound three years after tapping and further in Eritrea (Ogbazghi, 2001) explained some period (eg. 3-5 years) is necessary from wound healing in northern Ethiopia. Therefore, for *B.papyriera* trees to be tapped for the next production season the tapped tree have to recover well from wound. It is also suggested that if tapping (wounding) is undertaken on those trees with higher diameter size and avoid tapping on smaller trees. Since tapping creates multifaceted undesirable negative impacts on *B.papyrifera* trees and further intensive tapping leads to the production of non-viable seeds (Ros-Tonen *et al*., 1995; Abeje, 2002) and allows more starch to be oozed from the wound thus if tapping is applied to smaller trees consequently the tapped tree will face carbon starvation (Tefera, 2011). Particularly tapping at the lower tapping height (i.e. <1.3 m) is advised for this study.

Tapping height and diameter size on frankincense yield

The second objective of this study was evaluating the effect of tapping height and tree size (DBH) on the frankincense yield. For this we hypothesized higher tapping height and tree size (DBH) will bring higher frankincense yield. In line with our hypothesis the result revealed that trees with bigger diameter size (DBH) had shown higher frankincense yield (i.e. 204.3 g/tree/year) than that of smaller trees. On the other side, tapped trees at higher tapping height (1.5 m) gave lower frankincense yield (i.e. 39.7 g/tree/year) in which our stated hypothesis didn't meet in this case. Different scholars revealed different frankincense yield, for instance Tadesse *et al*. (2004) reported a range of 6.7-451.4 g/tree/year , Abeje and Asmamaw (unpub.) (2007) reported a frankincense yield of 207-352 g/tree/year and Girmay (2000) reported 500 g/tree/year of frankincense to be collected from *B.papyrifera* tree under normal frankincense production techniques. A similar study on the yield potential of *B.papyrifera* in the Metema area (Wubalem *et al*., 2004; Asmamaw and Abeje, 2007) revealed the potential of 67.5 kg of frankincense production from a hectare of Boswellia woodland, and Mesfin *et al*. (2007) also reported frankincense production per hectare from open and closed area in Tigray to be 254.18 kg and 169.08 kg, respectively. Generally, according to this study, tapped trees with a bigger tree (DBH) provide higher frankincense yield than smaller tree size (DBH) and in quantitative terms the value ranged from 39.7 g/tree/year to 204.3 g/tree/year and this value is not far from pervious study done on this tree species. Thus, the higher frankincense production from bigger

B.papyrifera trees observed in this study may be the result of larger photosynthesis carbon present acquisition capacity by bigger trees (Tefera, 2011) than that of smaller tree. In addition to the tapping diameter size bigger trees tapped at the lower height usually below diameter at breast height (i.e. <1.3 m) had yield higher frankincense yield than tapping done at higher height. This can be clearly justified in the following manner:- the diameter and the bark thickness of the tree usually at the lower height is thicker than at higher height and this attributed to a high accumulation of starch /carbon at the lower height than the higher one and therefore when tapping done at the lower height it will allow more resin to be oozed and the frankincense to be collected will be increased.

Conclusion and recommendation

Higher diameter will greatly favor the wound recovery rate of *B.payrifera* trees and the minimum tapping diameter size shall be limited to 16-20 cm of tapping height of lower (i.e. 0.5 m) and avoid tapping on smaller trees of any tapping height. Trees with higher diameter size (21-25 cm) with tapping height of less than diameter at breast height (i.e. <1.3 m) had brought higher frankincense yield than smaller diameter trees (i.e. 10-15 cm) size. Since carrying out tapping at higher tapping point did not produce higher frankincense yield and also wound recovery is slow. Therefore, avoid tapping on those trees with lower diameter size (10-15 cm) and higher tapping height (1.5 m). And finally to maximize the frankincense production and enhance the wound healing from individually tapped trees of adult *B.papyrifera* it is better to undertake tapping on those trees having bigger diameter size and avoiding tapping smaller trees. Further investigation on tapping intensity/number of tapping spot, tapping frequency, viability of seeds and insect/pest infestation is essential.

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