East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 6, Issue 1, 2023
Print ISSN: 2707-4315 | Online ISSN: 2707-4323
Title DOI: https://doi.org/10.37284/2707-4323

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia

Siraj Kelil[1]& Sisay Taye[1]*

[1] Oromia Agricultural Research Institute, P. O. Box 81265, Addis Ababa, Ethiopia.
[*] Author for Correspondence ORCID ID: https://orcid.org/0000-0003-0349-5486; email: sirajkelil99@mial.com

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Date Published:

27 July 2023

Keywords:

Gum-Resin, Frankincense, Tapping Materials, Yield, Tapping Diameter, Tapping Position.

ABSTRACT

Ethiopia is one of the Gum and Resin producing countries with a large potential. Borana pastoralists particularly utilised these resources as a source of revenue. The majority of Ethiopia's gum-resin products are collected from natural oozing. In southern Ethiopia, improved tapping mechanisms are uncommon. This study was conducted to determine the effect of different tapping machines and tapping at different tree diameter classes on the gum and incense yields of selected tree species. *Commiphora corrugata*, *Boswellia microphylla*, and *Boswellia neglecta* tree species were selected for their potential existence and economic importance. A factorial experiment was arranged in a randomised complete block design (RCBD) in which three types of tapping materials including natural oozing and three levels of tree size (diameter classes) were used. Accordingly, materials (Panga, Axe, Sonki, and control) were applied at diameters of (5-8 cm, 8.1-11 cm and >11 cm) for a tree height below DBH (at < 130 cm) and above DBH (at >130 cm) on selected tree species while natural oozing was remained untapped and used as controls. Accordingly, the highest mean yield was recorded for trees tapped by axe (5.99 g/tree), followed by Sonki (5.01 g/tree) and bigger diameter class >11 cm (7.10 g/tree) for *Commiphora corrugata*. The highest mean yield was also obtained for trees tapped by axe (10.76 g/tree) in the first year and (43.71 g/tree) in the second year and bigger diameter class >11 cm (15.16 g/tree) in the first year and (47.81 g/tree) in the second year for *Boswellia microphylla*. Moreover, the highest mean yield was recorded for naturally oozing trees (6.16 g/tree) and bigger diameter class >11 cm (6.33 g/tree) for *Boswellia neglecta*. Tapped trees generally provided significantly higher yields than untapped or control trees, and frankincense yield increased with increasing tree size.

APA CITATION

Kelil, S. & Taye, S. (2023). Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia *East African Journal of Forestry and Agroforestry*, *6*(1), 211-226. https://doi.org/10.37284/eajfa.6.1.1334

CHICAGO CITATION

Kelil, Siraj and Sisay Taye. 2023. "Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia". *East African Journal of Forestry and Agroforestry* 6 (1), 211-226. https://doi.org/10.37284/eajfa.6.1.1334

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

HARVARD CITATION

Kelil, S. & Taye, S. (2023), "Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia", *East African Journal of Forestry and Agroforestry*, 6(1), pp. 211-226. doi: 10.37284/eajfa.6.1.1334.

IEEE CITATION

K., Kelil, & S., Taye, "Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia", *EAJFA*, vol. 6, no. 1, pp. 211-226, Jul. 2023.

MLA CITATION

Kelil, Siraj & Sisay Taye. "Effect of Tapping on Gum and Incense Yield of Selected Trees Species in Elwaye and Dhas Districts, Borana Zone, Southern Oromia". *East African Journal of Forestry and Agroforestry*, Vol. 6, no. 1, Jul. 2023, pp. 211-226, doi:10.37284/eajfa.6.1.1334

INTRODUCTION

Ethiopia owns one of the extensive forest vegetation resources in the Horn of Africa (WBISPP, 2005). Gum and resin-producing species cover substantial areas of Ethiopia in arid and semi-arid lands. The country also has vast areas of arid and semi-arid lands, estimated at between 560,000 and 615,000 km^2, that can be considered potentially suitable for cultivating these gum and resin-producing species as tree crops (Mulugeta & Habtemariam, 2011). Ethiopia is well-endowed with various species of Acacia, Boswellia and Commiphora that are known to produce gum Arabic, frankincense, and myrrh, respectively (Tadesse *et al*., 2007). Several of these indigenous tree and shrub species have been known to yield economically valuable products for several millennia (Eshetu, 2002; Tadesse *et al*., 2004). Accordingly, Combretum-Terminalia woodlands, Acacia-Commiphora woodlands and lowland semi-desert and desert vegetation are known to harbour diverse high-value woody species, such as those that produce commercial gums and resins (i.e., gum Arabic, frankincense, and myrrh) (Abeje *et al*., 2005; Mulugeta & Habtemariam, 2011). Over 60 gum and resin-bearing species are found in the country, and out of the total areas of woodlands that cover the country, about 2.9 million ha have the potential to produce oleo-gum and resin (Girmay, 2000; Tadesse *et al*., 2007).

In terms of regional distribution, gum-resin-bearing woody species are found in almost all regions and occupy a significant portion of the landmass (Mulugeta *et al*., 2003; Jiregna *et al*., 2007; Adefires & Mohamed, 2008). In its economic importance, oleo-gum and resin collection and sale are reported to provide an income that ranked second after livestock in the livelihood of the pastoral community (Mulugeta *et al*., 2003). Moreover, the gum-resins-producing species provide essential socioeconomic and ecological services; the potential role they can play in the livelihood of local society and the nation at large is very significant (Mulugeta *et al*., 2003; Adefires *et al*., 2011). The gum and resins-products were collected to serve as a source of income generation and employment among local poor communities, mainly during slag periods (Adefires *et al*., 2011; Yasin & Salah, 2014). A study by Tadesse *et al*. (2007) at the household level carried out in one region of Ethiopia has shown that the gum resins business provides income about three times greater than the contribution of crop farming. A similar report from (Abdulla, 2013) in the Yabello district, Borana zone, indicated that the collection of NTFPs is the major source of cash income in this rural zone. The use of these products adds a crucial dimension to a diversified livelihood base and thus acts as a safety net, particularly when there is a shortfall in agricultural production to minimise risk and fill the gap of income shortage.

However, despite the enormous importance of gum and resin-bearing species' ecological and socioeconomic importance worldwide, these resources are under increasing anthropogenic and natural pressures (Adefires *et al*., 2012). This has been due to degradation resulting from agricultural expansion, overgrazing, fire, poor incense harvesting practices, etc. They are declining both in terms of size (deforestation) and quality of stands (degradation) at an alarming rate associated with the expansion of crop and

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

livestock production as well as human settlement, overgrazing, fuelwood, and charcoal production, anthropogenic fire, and poor tapping practices (Jiregna *et al*., 2007; Mulugeta & Habtemariam, 2011).

Most of the current gum Arabic production in Ethiopia is through collection from natural exudates (Mulugeta, 2005). The collection is mostly carried out by cattle herders, women, and children from tree trunks and branches. Tapping for the production of gum Arabic involves removing sections of the bark with a sharp material (e.g., an axe) (Girmay & Mulugeta, 2010). Tapping is practised to enhance yield quantity and quality. For instance, tapping activities increased gum Arabic yield by 77.42% as compared with untapped trees in Kenya (Wekesa *et al.*, 2009). However, gum Arabic production is low in Borana due to there being no artificial tapping activity used and the absence of organised collection in the area (Chikamai, 2003 & Abeje *et al*., 2005). It is also stated that the collectors are unaware of the process of tapping for the production of good quality and quantity gum Arabic (Mulugeta *et al*., 2003; Gizaw, 2006). Therefore, this study is initiated to investigate the effect of different taping materials, tree diameter class and tapping position on gum Arabic and incense yield, thereby identifying appropriate tapping materials and positions based on stem diameter for selected tree species.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted in the Dhas and Elwaya districts of the Borana zone. The surface area of Dhas district was 3183.22 km^2 and that of Elwaya was 3967. 12 km^2. Geographically Borana zone is situated between 4º to 6º N latitude and 36º to 42º E longitude (*Figure 1*). The altitude of the Borana zone ranges from 1000 – 1700 m above sea level, featured by isolated mountains and valleys (Coppock, 1994; McCarthy *et al*., 2002). Elwaya and Dhas districts are located at a distance of 590 and 730 km South of Addis Ababa, respectively (Teshome et al., 2019; DPDO, 2019). Borana is characterised by a semi-arid to arid climate (Kamara *et al*., 2005; Haile *et al*., 2011) and has two distinct rainfall peaks; 59% of annual precipitation occurs from March to May, while 27% occurs from September to November (Coppock, 1994). The topography consists of isolated mountains, valleys and depressions occupied almost entirely by pastoral and agro-pastoral populations (Coppock, 1994). Pastoralism is the main means of livelihood for the Borana people (Gelagay *et al*., 2007), and cattle, goats, sheep, and camels are important livestock raised in the area.

Ade-Gelchet Kebele is found between 4°37’26 “N to 4°55’2 “N latitude and 37°46’20” to 37°58’9 “E longitude with an average elevation of 1638.23 m above mean sea level and has a sloping topography towards the west. The total surface area of the Kebele was 703 km$^{2.}$ No site-specific climatic data are available for both study woredas and Keble; therefore, the weather data were obtained from the POWER Data Access Viewer v2.0.0 on 2022/12/27 using coordinates of 4.877 N and 37.9277E) and used to describe the climate of the study area (https://power.larc.nasa.gov/data-access-viewer/). Based on this, the mean annual minimum and maximum temperatures vary from 13.72 to 27.26 ºC, and the area receives a mean annual rainfall of 749.75 mm (*Figure 3*). The vegetation of the area is woodland, comprising of *Acacia-Commiphora* woodland vegetation types. Gum-resins-bearing tree species dominantly found in the area are *Acacia seyal*, *Acacia Senegal* var. *senegal*, *Commiphora corrugata* and *Boswellia neglecta.*

Dhas Kebele is found between 4°2’43” to 4 °23’4” N latitude and 38°35’9” to 38°53’32” longitude with an average elevation of 1641.83m above mean sea level and has a sloping topography towards the South. The total surface area of the Kebele was 825 sq. km. The weather data were downloaded from the POWER Data Access Viewer v2.0.0 on 2022/12/27 using the coordinate of 4.225N and 38.700E, and based on this, the mean annual minimum and maximum

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

temperatures vary from 14.63 to 27.33 ºC and the mean annual rainfall was 679.98 mm (*Figure 2*). The vegetation type of the area is *Acacia-Commiphora* woodland vegetation, and the dominant Gum-Resins bearing tree species found in the area are *Acacia senegal* var. Senegal, *Boswellia microphyll* and *Boswellia neglecta.*

Figure 1: Location of the study area

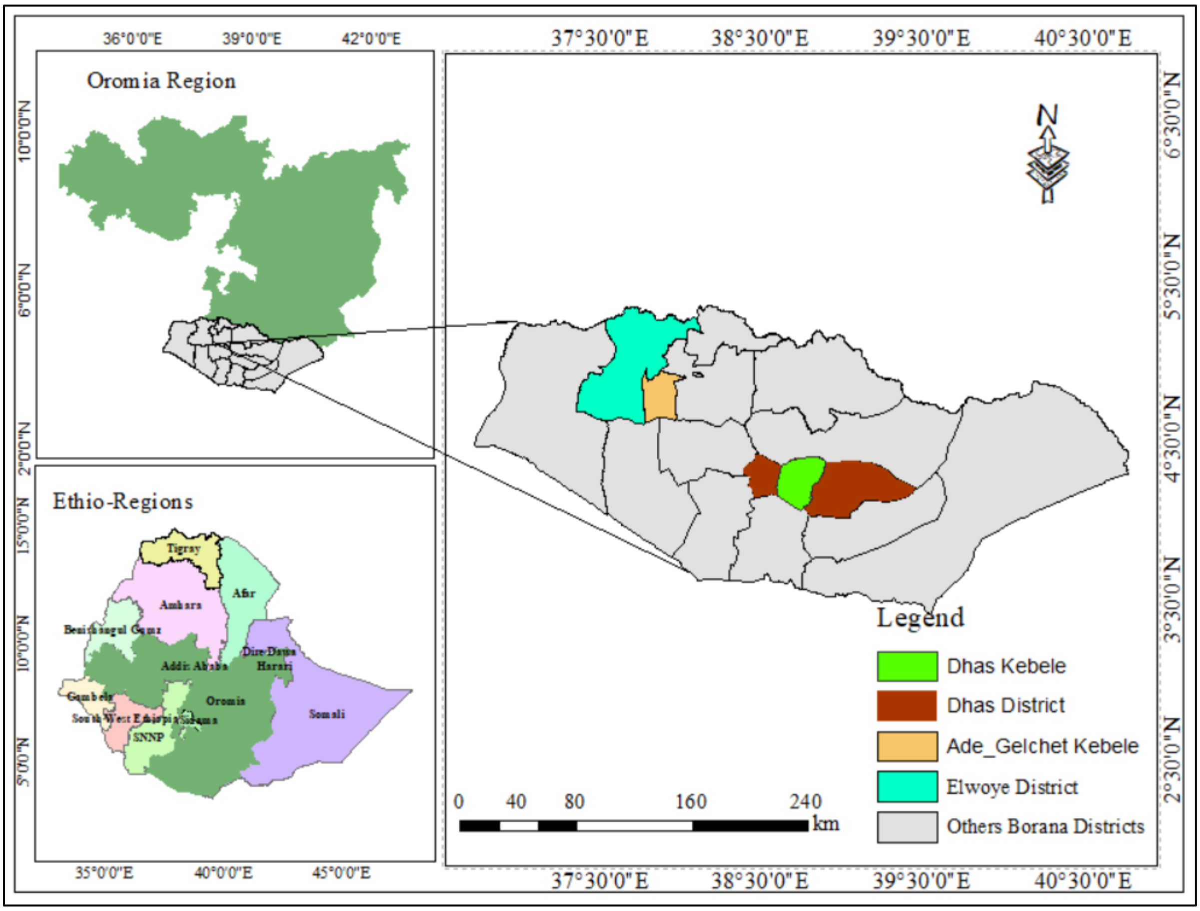
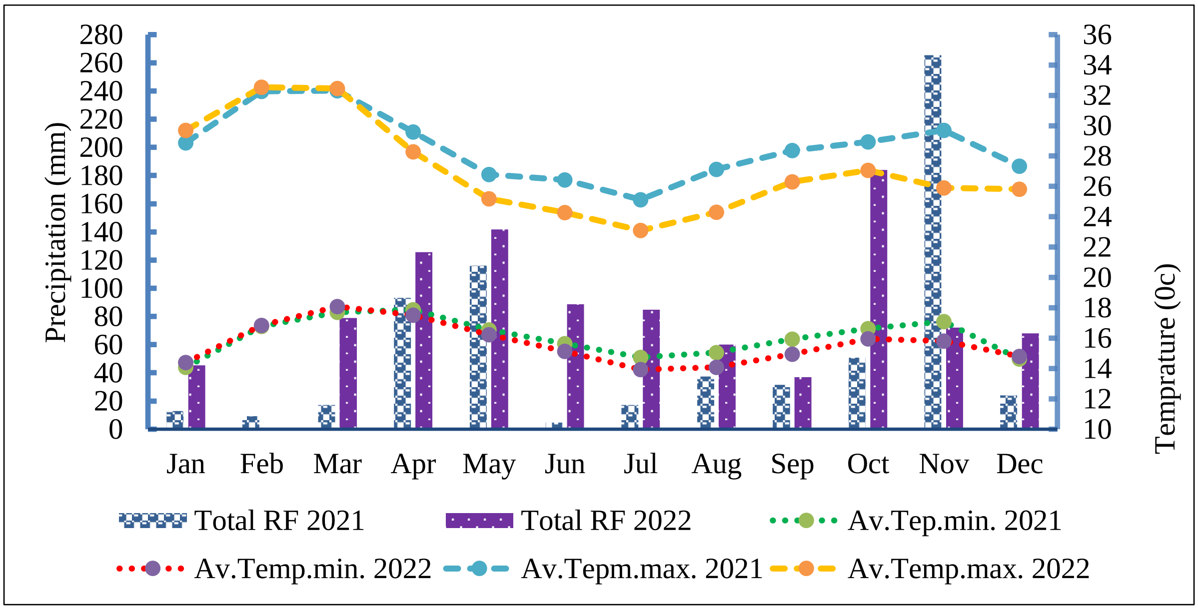


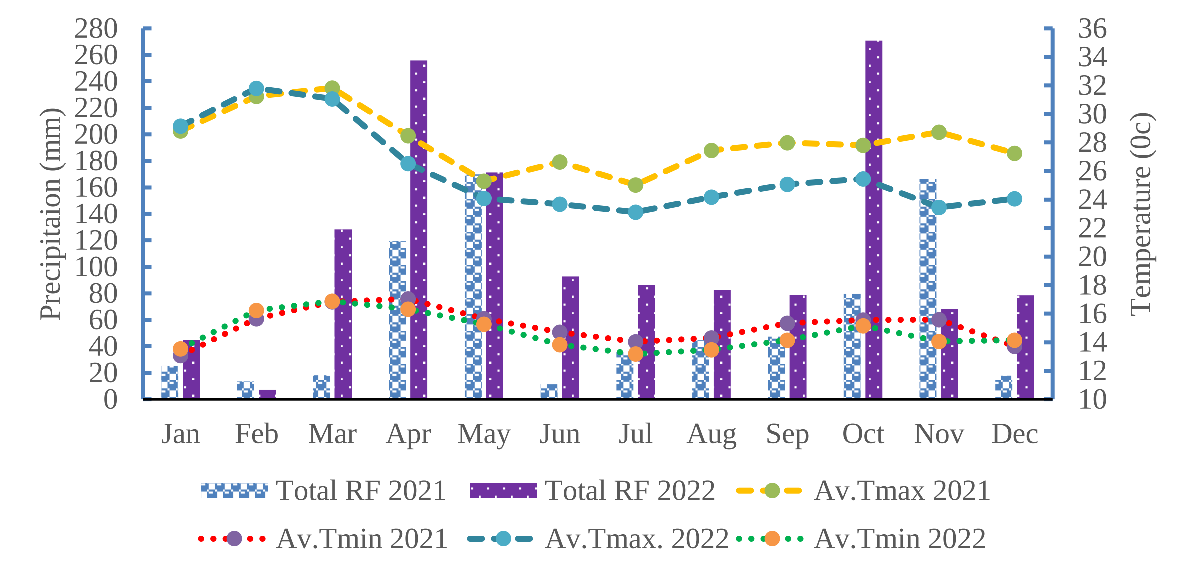
Figure 2: Total rainfall, average maximum, and minimum temperature of Dhas District in 2021 and 2022



Source of data: (POWER Data Access Viewer v2.0.0).

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Figure 3: Total rainfall, average maximum, and minimum temperature of Elwaya District in 2021 and 2022



Source of data: (POWER Data Access Viewer v2.0.0).

Methods

The secondary data were collected, and a reconnaissance survey was made in the woodland of the Borana zone in the Dhas and Elwaye districts. Based on this reconnaissance survey Dhas Kebele from the Dhas district and Adegelchet Kebele from the Elwaye district were selected for the study because of their potential area for gum and resin-bearing tree species in the Borana zone. Following this, three gum and resin-bearing tree species, namely; *Commiphora corrugata* (siltachoo), *Boswellia microphylla* (Ilkabuqis) and *Boswellia neglecta* (Dakkara), were selected for this study. After the selection of tree species, the sample plot was selected randomly and the experiment was arranged with 4 x 3 x 2 factorial RCBD. The first factor was three different tapping tools, namely Panga, Axe, Sonki, and control (Natural oozing). A study on *Acacia seyal* indicated tapping tools had a great influence on the amount of gum production (tone/ha) and sustainable production (Fadl & Gebauer, 2004). The second factor was the tree diameter class, which was tested in three diameter class levels (5.0-8.0 cm, 8.1-11.0 cm, >11 cm) following (Wekesa *et al.*, 2009). The third factor was tapping position (height), namely, below DBH (<130 cm) and above DBH (>130 cm).

The experiment was conducted on natural stands of gum and resin-bearing species in the woodlands of AdeGelchet and Dhas Kebele. In the selected woodland, the experiment was arranged in factorial RCBD with two replications in both Kebele. In each replication, five natural stand trees samples were selected for each treatment and classified according to the above-stated diameter classes using a calliper. After trees were classified into diameter classes, tapping practices were applied for each diameter class and tapping position (below DBH and above DBH) and tapped using selected tapping materials (Panga, Axe, and Sonki. Tapping incisions were made on the living bark on the east and west-facing sides of the trunk. The incision was done with a length of 10-15 cm and a width of 3 cm (Wekesa *et al.*, 2009). For natural oozing, sample trees were selected similarly to other tapping materials and marked, and incense collections were conducted similar time with other tapping materials under treatment. The experiment was conducted in both study sites during dry seasons (December to February in our study area) and repeated for two consecutive years in 2021 and 2022. Tapping incisions were made in mid-January, and the incense yield collection was made four weeks after tapping was applied for each species in both years. Because tapping was applied for the initial time, the required yield

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

was obtained after four weeks. In the case of reopening the incisions, the resin is often harvested every three weeks (Peter, 2006; Eshete *et al*., 2012). The collected incense yields were dried at room temperature for 72 hours (Mohammed & Rohle, 2009) and determined by weighing on the sensitive balance.

Table 1: Treatment combinations

No	Tapping Material	Diameter Classes (cm)	Height (Position) (cm)
1	Panga (Banga)	≤ 8	Above 130 cm
2	Axe	8.1 -11	Below 130 cm
3	Sonki	>11	
4	Natural oozing (control)		

Panga (Banga) is a *farm tool that is used cut woody plants for local construction and used for weeding crops.*
An axe *is a local farm tool made up of metal and woolds that is used for everything from splitting firewood to felling trees and coppice work.*
Sonki *is originally developed by the Agricultural Research Corporation for tapping Acacia senegal (Fadl and Gebauer 2004).*

Plate 1: Tools used for tapping

Data Collection and Analysis

Data recorded during the experiment were the diameter class of each tree species and gum/incense yield. Finally, data were subjected to analysis of variance using SAS statistical software. Data collated from different species were analysed separately by species. The homogeneity of data collected from different locations and in different years was tested using Levene's test procedures. Because the year I and year II data for *Boswellia neglecta* and *Commiphora corrugata* were similar, combined data analysis was performed on those data; however, the year I and year II data for *Boswellia microphylla* required separate analysis. The treatment means that were significantly different at a 5% level of significance were separated using the LSD test.

RESULTS AND DISCUSSION

Effects of Treatments on Incense Yield of *Commiphora corrugata*

The analysis of variance indicated that incense yield differed significantly ($P < 0.001$) among the different tapping materials and diameter classes (*Table 2*). The analysis of variance also showed there was a significant tapping material and diameter class interaction effect on frank incense yield.

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

The maximum yield was observed under trees tapped by axe (5.99 g/tree), followed by trees tapped by Sonki (5.01 gm/tree); while the lowest yield was observed under untapped trees (4.18 gm/tree). The results of this study clearly show that tree stem diameter (dbh) showed significant differences at ($p < 0.001$) in resin yield between the different tree diameters (*Table 3*). Accordingly, the yield of frankincense increased with increasing tree size (diameter). Thus, the yield obtained from the <8 cm, 8.1-11 cm and >11 cm dbh trees/diameter class was 3.72, 4.06 and 7.10 g per tree, respectively. The highest resin production was obtained from the largest trees (dbh >11 cm). Moreover, there is no significant difference ($p > 0.05$) observed in the yield of frank incense among the tapping position of these tree species implying that the tapping position evaluation had no effect on the quantity of incense for this tree species in the study sites.

There was a significant interaction effect ($p < 0.01$) of tapping materials and diameter classes in the mean incense yield of *Commiphora corrugata*. Hence, the highest frankincense yield was obtained from a tree in the largest diameter classes (>11 cm) tapped with an axe (8.62 g/tree), followed by trees tapped by Panga in similar diameter classes (6.78 g/tree); while the lowest frankincense yield was obtained from smallest diameter class (<8 cm) tapped with Panga (3.54 g/tree) and Sonki (4.1 g/tree) comparing to the three tapping materials.

Table 2: Analysis of Variance of tapping data of *Commiphora corrugata*

Source	DF	Sum of Squares	Mean Square	F-Value	P-value
Study Years	1	11.32	11.32	7.94	0.005
Tapping Material	3	72.24	24.08	16.90	< 0.001
Tapping Position	1	3.64	3.64	2.55	0.112
Diameter class	2	457.29	228.64	160.48	< 0.001
Material * Position	3	0.78	0.26	0.18	0.909
Material * Diameter class	6	28.87	4.81	3.38	0.004
Material * Year	3	4.16	1.39	0.97	0.407
Position * Diameter class	2	2.29	1.14	0.80	0.45
Position * Year	1	1.48	1.48	1.04	0.309
DBH * Year	2	12.06	6.03	4.23	0.016
Material * Position * Diameter class	6	9.67	1.61	1.13	0.347
Material * Position * Year	3	0.48	0.16	0.11	0.953
Material * Diameter class * Year	6	16.47	2.74	1.93	0.08
Position * Diameter class * Year	2	0.65	0.32	0.23	0.797
Material * position * Diameter class * Year	6	3.04	0.51	0.36	0.906
Error	148	210.86	1.43		

Table 3: Mean (± standard error) incense yield (gm/a tree) of *Commiphora corrugata*

		Mean yield (gm/tree)
Study years	2022	5.21 ± 0.13^{a}
	2021	4.70 ± 0.13^{b}
Tapping materials	Axe	5.99 ± 0.18^{a}
	Sonki	5.01 ± 0.18^{b}
	Panga	4.652 ± 0.16^{bc}
	Natural oozing	4.18 ± 0.21^{c}
Tapping position	Above DBH	4.81 ± 0.13^{a}
	Below DBH	5.11 ± 0.13^{a}
Diameter class	>11 cm	7.10 ± 0.13^{a}
	8.1 -11 cm	4.06 ± 0.16^{b}
	≤8 cm	3.72 ± 0.17^{b}
CV		39.83

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Table 4: Interaction effects of tapping materials, diameter classes on frankincense yield of *Commiphora corrugata*

Tapping Materials	Diameter class	Mean± *Std. E.* yield (gm/a tree)
Axe	>11 cm	8.62±0.26[a]
	8.1 -11 cm	4.99±0.36[c]
	≤ 8 cm	4.36±0.3c[d]
Panga	>11 cm	6.78±0.27[b]
	8.1 -11 cm	3.64±0.28[d]
	≤ 8 cm	3.54±0.3[d]
Natural oozing	>11 cm	6.68±0.25[b]
	8.1 -11 cm	2.97±0.34[d]
	≤ 8 cm	2.89±0.46[d]
Sonki	>11 cm	6.31±0.29[b]
	8.1 -11 cm	4.63±0.32[cd]
	≤ 8 cm	4.1±0.31[cd]

We found that tapped *Commiphora corrugata* trees generally provided higher yield than untapped trees, and the maximum gain in yield was observed under trees tapped by axe, followed by trees tapped under Sonki, while the lowest gain in yield was observed under untapped trees. This finding confirms similar studies in Southern Ethiopia, where tapping yielded far more yield than untapped trees (Semegnew *et al.*, 2016).

In terms of diameter class, the highest resin production was obtained from the largest trees (dbh >11 cm), over 7 g per tree. This result was also consistent with the works of Abbas *et al.* (2009) on *Boswellia papyrifera* in South Sudan frankincense yield, which was obtained from 10 - 15 cm and 16-20 cm stem diameter being 60% and almost 38% lower than that of stems over 20 cm stem diameter. Moreover, A study on other species in Southern Ethiopia and Western Sudan showed gum Arabic yield increased with increasing tree size /diameter (Ballal *et al*., 2005). Tapping position had no effect on the quantity of frankincense for this tree species in the study sites. Generally, frankincense can be wounded, and the incense yield can be harvested after a month. This means that in the practical situation of the study area, gum and incense yield can be collected by making incisions around the trunk of the tree three times a year during the dry season (December to February in our study area). Accordingly, in the study area, on average, 17.97 gm of incense can be harvested per *Commiphora corrugata* tree per year. Resin is often harvested every three weeks by reopening the incisions, and harvesting occurs continuously throughout the dry season (Peter, 2006; Eshete *et al*., 2012).

Effects of Treatments on Frankincense Yield from *Boswellia microphylla*

The yield obtained from *B. microphylla* in 2021 was lower than that of 2022. (*Table 7*). Analysis of variance pointed out that there were significant differences among tapping materials (Axe, Panga, and natural oozing) both in the 2021 and 2022 study years ($F = 4.38$, $P < 0.01$; $F = 37.47$, $P < 0.001$) respectively (*Table 5*).

The frankincense yield obtained from *Boswellia microphylla* tapped by axe was highest (10.76 ± 0.8 gm/tree in 2021 and 43.71 ± 1.97 gm/tree in 2022) than those tapped with Panga, Sonki, and natural oozing in both years. The lowest yield was obtained from natural oozing, which was 8.32 ± 0.73 gm/tree in 2021 and 14.19 ± 1.97 gm/tree in 2022. The yield obtained from a tree tapped by Panga and Sonki was not significantly different from each other. However, better than the yield obtained from natural oozing and lower than that of the tree tapped by Axe (*Table 6*).

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Table 5: Analysis of Variance (ANOVA table) of treatments effects on yield of *Boswellia microphylla*

Year	Source of Variation	Df	Sum of Squares	Mean Square	F-value	P- value
Year I (2021)	Materials	3	247.95	82.65	4.38	0.007
	Position	1	12.24	12.24	0.65	0.423
	Diameters Class	2	2196.43	1098.22	58.16	< 0.001
	Materials *position	3	33.10	11.03	0.58	0.627
	Materials * Diameters Class	6	375.21	62.54	3.31	0.006
	Position * Diameters Class	2	85.83	42.92	2.27	0.11
	Materials *position* Diameters	6	137.69	22.95	1.22	0.308
	Error	73	1378.56	18.88		
Year II (2022)	Materials	3	15745.40	5248.47	37.47	< 0.001
	Position	1	3574.55	3574.55	25.52	< 0.001
	Diameters Class	2	33177.50	16588.75	118.43	< 0.001
	Materials *Position	3	3774.75	1258.25	8.98	< 0.001
	Materials * Diameters Class	6	7567.92	1261.32	9.01	< 0.001
	Position * Diameters Class	2	559.82	279.91	2.00	0.14
	Materials *Position *Diameters	6	1732.05	288.68	2.06	0.063
	Error	120	16808.44	140.07		

The effects of tapping potions (the upper and lower part of a tree) showed irregular trends. There was no significant difference between the two tapping positions (above and below DBH) in 2021(F= 0.65, P > 0.05); however, the two tapping position was a significant difference in 2022 (F= 25.52, P < 0.001) (*Table 5*). The frankincense yield of *B. microphylla* obtained from below DBH (33.64 ±1.39 gm/a tree) was greater than that of above DBH (23.67 ±1.39 gm/tree) in 2022 (*Table 6*). Even though there was no statistically different, the yield collected from below DBH was also greater than that collected from Above DBH in 2021.

In terms of diameter classes, a significant difference was observed in frankincense yield of *B. microphylla* among the three diameter classes in both 2021 (F = 58.16, P< 0.001) and 2022 (F=118.43, P< 0.001) study years (*Table 5*). The highest yield was obtained from trees in the largest diameter class (>11 cm) than other classes, and the lowest yield was obtained from the smaller diameter class (< 8 cm) in both the 2021 and 2022 study years (*Table 6*).

Table 6: Mean (± standard error) incense yield (gm/a tree) of *Boswellia microphylla*

		Year I (2021)	Year II (2022)
Tapping Materials	Axe	10.76 ± 0.8a	43.71 ± 1.97[a]
	Panga	10.69 ± 1.18ab	29.17± 1.97[b]
	Sunkey	8.26 ± 0.8bc	27.54 ± 1.97[b]
	Natural oozing	7.74 ±1.07c	14.19 ± 1.97[c]
Tapping Position	Below DBH	9.12 ± 0.66[a]	33.64 ±1.39[a]
	Above DBH	8.32 ± 0.73[a]	23.67 ±1.39[b]
Diameter Classes	>11 cm	15.16 ± 0.69 a	47.81 ±1.71[a]
	8.1 -11 cm	8.42 ± 0.84b	27.46 ± 1.71[b]
	≤ 8 cm	2.54 ± 0.98c	10.69 ± 1.71[c]
CV		45.25	33.21

There was no significant interaction effect observed among the tapping materials, tapping position, and diameter classes. The significant interaction effects were detected between tapping materials and diameter class in both the 2021 and 2022 study years; (F= 3.31, P< 0.01) and (F= 9.01, P< 0.001), respectively (*Table 5*). The highest frankincense yield of *B. microphylla* (21.08

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

gm/tree) was recorded from a tree >11 cm diameter class tapped with an axe, while the lowest yield (2.33 gm/tree) was recorded from natural oozing trees with < 8 cm diameter class in 2021 (*Table 7*).

Table 7: Interaction effects of tapping materials and diameter class on frankincense yield of *Boswellia microphylla*

Tapping Material	Diameter Classes	Mean yield (gm/a tree)	
		Year II (2021)	Year II (2022)
Axe	>11 cm	21.08 ±1.32[a]	71.05 ± 3.42a
	8.1 -11 cm	8.59 ±1.32[cd]	48.75 ± 3.42b[b]
	≤ 8 cm	2.69 ± 1.54[e]	11.325 ± 3.42[cd]
Panga	≥11 cm	14.38 ± 1.54[b]	53.825 ± 3.42[b]
	8.1-11 cm	12.38 ± 1.98[bc]	23.092 ± 3.42[cd]
	≤ 8 cm	2.47 ± 2.51[e]	10.592 ± 3.42[cd]
Sunkey	>11 cm	14.91 ± 1.37[b]	42.196 ± 3.42[b]
	8.1 -11 cm	6.63 ± 1.32[d]	27.613 ± 3.42[cd]
	≤8 cm	2.70 ± 1.45[e]	12.821 ± 3.42[cd]
Natural oozing	>11 cm	10.34 ±1.32[c]	24.175 ± 3.42[c]
	8.1-11 cm	6.08 ± 1.98[de]	10.375 ± 3.42[cd]
	≤8 cm	2.33 ± 2.17[e]	8.017 ± 3.42[d]

Boswellia microphylla is one of the resins-bearing tree species dominantly found in the Dhas district of Borana Zone. In the present study, the incense yield obtained from *a B. microphylla* tree varied between the study years, with the highest recorded in the second year. This might be because of the atmospheric temperature variation over the two years. Frankincense production can be affected by a physiological process, such as tapping practices and atmospheric conditions. In the Borana lowland, 2022 was drier and hotter than in 2021, and at the Dhas study site, there was no rainfall during the data collected for a month in February 2022 (*Figure 2*).

The frankincense yield obtained from *Boswellia microphylla* tapped by axe was highest than those tapped with Panga, Sonki, and natural oozing in both study years. The lowest yield was obtained from natural oozing. Tapping by axe increases the frankincense yield by 17% on average compared to natural oozing. The yield obtained from a tree tapped by Panga and Sonki was not significantly different from each other; however, better than the yield obtained from natural oozing and lower than that of the tree tapped by an axe.

In terms of tapping positions and diameter, in both study years, the average incense yield of *B. microphylla* collected from below DBH was greater than that collected from Above DBH and the highest yield was obtained from the largest diameter class trees (>11 cm) and the lowest yield was obtained from the smaller diameter class trees (< 8 cm) in both the 2021 and 2022 study years. This result is consistent with the studies on *Boswellia papyrifera* pointed out that the highest resin production is obtained from the largest diameter trees than the smallest (Abbas *et al*., 2009, Elias *et al*., 2020). This result was in contrast with the works of Semegnew *et al*. (2016) stated that the highest yield of *Acacia senegal* gum Arabic was obtained from trees in the smallest diameter class than the largest classes. This may be due to species variation. In general, the average incense yield of *Boswellia microphylla* tree tapped using an axe per season is estimated to be about 81.71 gm/tree/year.

Effects of treatments on Incense Yield of *Boswellia neglecta*

Analysis of variance revealed that there was no significant difference in the mean yield of two study locations and study years. Significant differences were observed among tapping materials ($P < 0.001$), diameter classes ($p < 0.001$), and between tapping positions ($P<0.01$) (*Table 8*).

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Table 8: Analysis of Variance (ANOVA table) of treatments effects on *Boswellia neglecta*

Source of Variations	DF	Sum Sq	Mean Sq	F value	Pr (>F)
Location	1	1.22	1.22	0.34	0.560
Year	1	0.75	0.75	0.21	0.647
Tapping Materials	3	356.09	118.70	33.27	< 0.001***
Tapping Position	1	25.76	25.76	7.22	0.008**
Diameter classes	2	616.08	308.04	86.35	< 0.001***
Location*Year	1	52.54	52.54	14.73	< 0.001***
Location*Material	3	20.34	6.78	1.90	0.131
Location*Position	1	6.70	6.70	1.88	0.172
Year*Position	2	26.42	13.21	3.70	0.026*
Mat*Position	3	6.59	2.20	0.62	0.605
Location*Diameter class	1	1.81	1.81	0.51	0.478
Year*Diameter class	2	23.08	11.54	3.23	0.041
Material*Diameter class	3	108.23	36.08	10.11	< 0.001***
Position*Diameter class	6	227.95	37.99	10.65	< 0.001***
Location*Position	2	20.53	10.27	2.88	0.058
Location*Year*Material	3	45.17	15.06	4.22	0.006**
Location*Year*Position	1	0.01	0.01	0.00	0.970
Location*Material*Position	2	50.52	25.26	7.08	0.001**
Year*Material*Position	3	18.76	6.25	1.75	0.157
Location*Year*Diameter class	6	28.70	4.78	1.34	0.240
Location*Material*Diameter class	2	2.22	1.11	0.31	0.733
Year*Material*Diameter class	3	7.76	2.59	0.73	0.538
Location*Position*Diameter class	6	19.58	3.26	0.92	0.485
Year*Position*Diameter class	2	5.62	2.81	0.79	0.456
Material*Position*Diameter class	6	64.51	10.75	3.01	0.008**
Location*Year*Material*Position	2	17.04	8.52	2.39	0.094
Location*Year*Material*Diameter class	5	14.97	2.99	0.84	0.523
Location*Year*Position*Diameter class	2	5.49	2.74	0.77	0.465
Location*Material*Position*Diameter class	4	15.69	3.92	1.10	0.358
Year*Material*Position*Diameter class	6	20.28	3.38	0.95	0.462
Location*Year*Material*Position*Diameter class	2	3.67	1.84	0.51	0.599
Error	208	742.01	3.57		

The result of this study indicated frankincense yield of *B. neglecta is* better under natural oozing. The yield obtained from natural oozing was significantly highest (6.155 gm/tree) as compared to other tapping materials. In the case of diameter classes similar to other species, the highest incense production was obtained from the largest diameter class trees (dbh >11 cm) over 6.16 gm per tree (*Table 9*) and the lowest yield was obtained from smaller size trees (2.07 gm/tree). The position of tapping also had a significant effect on the resin production of *B. neglecta.* Trees produced a higher resin yield of 4.42 gm/tree from above DHB than below DBH, which was about 3.62 gm/tree.

There was a significant interaction effect of tapping material, Tapping position, and diameter class on the frankincense yield of *B. neglecta* (F=3.01, P<0.01). The highest yield was recorded from natural oozing collated from the top of a tree (above DBH) in the largest diameter classes >11 cm (13.47 ± 0.50 gm/tree), followed by natural oozing from below DBH of similar diameter class (7.65± 0.52 gm/tree) (*Table 10*). The frankincense yield of *B. neglecta* obtained from a tree diameter class greater than 11 cm tapped at the above DBH position by axe was (7.10 ± 0.60 gm/tee) the best next to the yield obtained from natural oozing. The lowest frankincense yields were obtained from the above DBH position of smaller diameter

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

trees tapped by Panga (1.46±0.771), Sonki (1.56 ± 0.64), and Axe (1.61 ± 0.66).

Table 9: Mean (± standard error) incense yield (gm/a tree) of *Boswellia neglecta*

Treatments	Levels	Mean yield (gm/a tree)
Tapping Materials	Natural oozing	6.155±0.238[a]
	Axe	3.386±0.257[b]
	Sonki	3.246±0.242[b]
	Panga	3.072±0.263[b]
Diameter Classes	> 11 cm	6.33±0.19[a]
	8.1 - 11 cm	3.49±0.23[b]
	≤ 8 cm	2.07±0.23[c]
Tapping Position	Above DBH	4.42±017[a]
	Below DBH	3.62±017[b]
CV		43.27

Table 10: Mean ± Std. Error of incense yield of tapping materials*tapping position*DBH class for *Boswellia neglecta*

Tapping Materials	Diameter Classes	Tapping Position	Yield (gm/ a tree)
Natural oozing	> 11 cm	Above DBH	13.47 ± 0.50[a]
Natural oozing	> 11 cm	Below DBH	7.65± 0.52[b]
Axe	> 11 cm	Above DBH	7.10 ± 0.60[b]
Natural oozing	8.1- 11 cm	Above DBH	6.66 ± 0.51[b]
Sonki	> 11 cm	Below DBH	5.54 ± 0.62[bc]
Panga	> 11 cm	Below DBH	4.34 ± 0.50[c]
Axe	> 11 cm	Below DBH	4.29 ± 0.56[c]
Panga	> 11 cm	Above DBH	4.279 ± 0.47[c]
Sonki	> 11 cm	Above DBH	4.17 ± 0.51[c]
Natural oozing	8.1 - 11 cm	Below DBH	4.04 ± 0.71[cd]
Sonki	8.1 -11 cm	Below DBH	3.09 ± 0.56[cd]
Panga	8.1 -11 cm	Above DBH	3.07 ± 0.68[cd]
Natural oozing	≤8 cm	Above DBH	2.79 ± 0.55[cd]
Axe	8.1 -11 cm	Below DBH	2.77 ± 0.59[cd]
Panga	8.1 -11 cm	Below DBH	2.63 ± 0.67[cd]
Sonki	8 .1-11 cm	Above DBH	2.59 ± 0.68[cd]
Axe	8.1 - 11 cm	Above DBH	2.59 ± 0.76[cd]
Sonki	≤ 8 cm	Below DBH	2.36 ± 0.55[cd]
Natural oozing	≤ 8 cm	Below DBH	2.32 ± 0.68[cd]
Panga	≤ 8 cm	Below DBH	2.25 ± 0.75[cd]
Axe	≤8 cm	Below DBH	1.87 ± 0.64[d]
Axe	≤ 8 cm	Above DBH	1.61 ± 0.66[d]
Sonki	≤ 8 cm	Above DBH	1.56 ± 0.64[d]
Panga	≤ 8 cm	Above DBH	1.46±0.771[d]

Boswellia neglecta is naturally grown in both study sites (Adegelchet and Dhas) of Borana woodland. The result of this study indicated incense yield of *B. neglecta is* better under natural oozing. The yield obtained from natural oozing was highest as compared to other tapping materials. The results would suggest that there is no impact of tapping trees on the frankincense yield *of B. neglecta.* We found small worms in the natural oozing, which may be contributing to high yielding under natural oozing. However, only a few individual trees/arcs of the area give the products. In the case of diameter classes similar to other species, the highest resin production was obtained from the largest diameter class trees, over 6.16 gm per tree and the lowest yield was obtained from smaller-size trees. The position of tapping had a significant effect on the resin production of *B. neglecta*. Trees produced a higher resin yield of above DHB than below DBH. The results, in line with the findings of a study by Abbas *et al*. (2009), found the resin yield of *B. papyrifera* was highest at tapping above 150 cm from the base of trees. The highest yield was recorded under natural oozing collated from the above position of a tree (above DBH) of a tree DBH greater than 11 cm. The lowest frankincense yields were obtained from the above DBH position of smaller diameter trees tapped by Panga and Axe. Generally, there was a significant and positive correlation between tree diameter size and frankincense yields of *B. neglecta* trees. The average incense yield from the natural oozing of *Boswellia neglecta* (Dakkara) is about 18.47 gm/tree/dry season.

Plate 2: Small worms found in the natural oozing

CONCLUSIONS AND RECOMMENDATIONS

Commiphora corrugata, Boswellia microphylla and Boswellia neglecta are among the gum-resins-bearing tree species naturally grown in Borana rangelands. Gum resins from these species are collected from natural exudates and no tapping practices at all by local communities. The producers are mainly herdsmen, women, and children, and they do the collection side by side with herding and other activities. A key result in the present study found that tapping of *Commiphora corrugata* and *Boswellia microphylla* increases frankincense yield by 17% on average compared to natural oozing. The maximum yield was observed under trees tapped by an axe when compared to Panga, Sonki, and natural oozing. However, the frankincense yield obtained from *Boswellia neglecta* was highest under natural oozing compared to tapping. We found small worms in the natural oozing, which may be contributing to better yield under natural oozing. In the case of diameter classes, the highest gum-resins yields were obtained from large-size trees (dbh >11 cm) for all species. In general, gum and resin yields can be collected three times in a dry season per year in the study area. Accordingly, an average of 17.97 gm and 81.71 gm of incense can be harvested per a *Commiphora corrugata* and *Boswellia microphylla* trees per a dry season, respectively, tapping by the axe; while a *Boswellia neglecta* tree can produce about 18.47 gm frankincense yield through natural oozing per a dry season.

Therefore, to get a better yield from *Commiphora corrugata* and *Boswellia microphylla* species axe was the better and should be taken as the recommended tool for tapping, and tapping at lower parts of the stem of larger size trees provides a better yield of frankincense. For *Boswellia neglecta, the* highest yield was obtained from natural oozing; consequently, more studies are needed on the contributions of the worms naturally found in natural oozing. Moreover,

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

further research should be done on long-term tapping effects on yields, healthy trees, and vulnerability to insect damage.

ACKNOWLEDGMENTS

The authors express their gratitude to Oromia Agricultural Research Institution for funding the projects and appreciate the staff of Yaballo Pastoral and Dryland Research Centre for helping and facilitating the fieldwork activities. The authors also gratefully appreciate pastoral communities in Adegelchet and Dhas Kebeles for supporting and guarding the experiment on the field throughout the lifetime of the activity.

REFERENCES

Abbas, H., Kamal, E. & Idris, M. (2009). Effect of position of tapping, tree stems diameter and tapping tools on frankincense yield of *Boswellia papyrifera* in South Kordofan state, Sudan. *Forests, Trees and Livelihoods,* 19(1), 19-26.

Abdulla, M. (2013). Contribution of Non-timber Forest Products to Household Food Security: The Case of Yaballo Woreda, Borana Zone, Ethiopia. Food Science and Quality Management, 20, 1–13.

Abeje, E. Demel, T. & Hakan H. (2005). The socioeconomic importance and status of populations of *Boswellia Papyrifera* (Del.) Hochst. in Northern Ethiopia: the case of North Gonder Zone. *Forests, Trees and Livelihoods*, 15(1), 55–74.

Adefires, W. Demel, T., Mulugeta, L. & Masresha F. (2012). Diversity, regeneration status, and population structures of gum and resin producing woody species in Borana, Southern Ethiopia. *Forests, Trees and Livelihoods*, 21(2), 85–96.

Adefires, W. & Abdile, M. (2008). Assessment of the resources base and socioeconomic importance of gum resources of selected zones in Somali Regional State.

Adefires, W., Mulugeta, L., Masresha, F.& Demel T. (2011). Socioeconomic importance of rum and resin resources in the dry woodlands of Borana, Southern Ethiopia. *Forests, Trees and Livelihoods,* 20, 137–55.

Ballal, M., Siddig, A., Fadl, E. & Luukkanen M. (2005). Gum arabic yield in differentially managed *Acacia senegal* stands in western Sudan. *Agro-forestry Forum*, 63, 237-245.

Chikamai N. (2003). Review and synthesis on the state of knowledge of *Boswellia* species and commercialisation of frankincense in the drylands of Eastern Africa.

Coppock L. (1994). The Borana pleatue of southern Ethiopia: Synthesis of pastoral research, development and change, 1980-91. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. P. 393.

[DDPDO] Dhas District pastoral and development office (2019). Physical and socioeconomic profile of Dhas District: annual report. Borbor, Ethiopia.

Elias, C., Abrham, A., Ambachew, G., Kibruyesfa, S. & Tatek D. (2020). Tapping height and season affect frankincense yield and wound recovery of *Boswellia papyrifera* trees, *Journal of Arid Environments*, 179, 104-176.

Eshete, A., Teketay, D., Lemenih, M., & Bongers, F. (2012). Effects of resin tapping and tree size on the purity, germination and storage behavior of Boswellia papyrifera (Del.) Hochst. seeds from Metema District, northwestern Ethiopia. *Forest Ecology and Management*, *269*, 31-36.

Eshetu A. 2002. Regeneration status, soil seed banks and socio-economic importance of *Boswellia papyrifera* in two woredas of northern Gondar zone, Ethiopia. [Master's thesis]. Sweden: Swedish university of agricultural sciences.

Fadl KE, Gebauer J. 2004. Effect of different tapping tools and different tapping positions on 'talh gum' yield of *Acacia seyal* var. *seyal* in South Kordofan, Sudan. Conference on international agricultural Research for Development; October 5-7; Berlin. Deutscher Tropentag.

Gelagay, A., Teshale, S., Amsalu, W. & Esayas, G. (2007). Prevalence of contagious caprine pleuropneumonia in the Borana pastoral areas of Ethiopia. *Small Rumin. Res*., 70 (2), 131–135.

Girmay, F. & Mulugeta L. 2010. Production, handling and quality control. In: Lemenihn M, Kassa H, editor. Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia. Indonesia. CIFOR: Bogor. P. 47-67.

Girmay F. (2000). The Status of gum arabic and resins in Ethiopia. In: Chikamai BN, editor. NGARA 2000. *Proceedings of the Network for Natural Gums and Resins in Africa (NGARA)* p 29–31. Nairobi, Kenya.

Gizaw AW. (2006). Population status and socioeconomic importance of gum and resin bearing species in Borana Lowlands, southern Ethiopia. Master's thesis, Addis Ababa, Ethiopia: Addis Ababa University.

Haile, A., Ayalew, W., Kebede, N., Dessie, T. & Tegegne A. (2011). Breeding strategy to improve Ethiopian Borana cattle for meat and milk production. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 26, ILRI. Nairobi, Kenya.

Jiregna, G., Lisanework, N. & Heluf G. (2007). Potential, distribution, ethno-botany and tapping procedures of gum producing *Acacia* species in the Somali Region, Southeastern Ethiopia. *East African Journal of Sciences*, 11, 69–78.

Kamara, A., Kirk, M. & Swallow B. (2005). Property rights and land use change: implications for sustainable resource management in Borana, Southern Ethiopia. *Journal Sustain. Agric*., 25, 41–61.

McCarthy, N., Kamara A. & Kirk M. (2002). The effect of environmental variability on livestock and land use management: the Borana plateau, Southern Ethiopia. Socioeconomics and Policy Research Working Paper 35, P. 35, Nairobi Kenya: ILRI and Washington DC: IFPRI.

Mohammed, M.& Rohle, H., (2009). Effect of tree density and tapping techniques on Productivity of gum talha from *Acacia seyal* var. *seyal* in South Kordofan, Sudan. Conference on International Research on Food Security, Natural Resource Management and Rural Development; October 6-8; Tharandt, Germany: University of Hamburg.

Mulugeta, L. (2005). Production and marketing of gums and gum resins in Ethiopia. In: Chikamai B. & Casadei E. (Eds), *Production and marketing of gum resins: frankincense, myrrh, and opoponax. Network for natural gums and resins in Africa* (Publication Series 5, pp. 55–70). Nairobi, Kenya.

Mulugeta, L., Tarekegn A., & Mats O. (2003). Gum and resin resources from some *Acacia*, *Boswellia*, and *Commiphora* species and their economic contributions in Liban, South-East Ethiopia. *Journal of Arid Environments*, 55(3), 465–82.

Mulugeta, L. & Habtemariam K. (2011). Opportunities and Challenges for Sustainable Production and Marketing of Gums and Resins in Ethiopia. *CIFOR*, Bogor, Indonesia.

POWER Data Access Viewer v2.0.0. (2022). The data was obtained from the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program. https://power.larc.nasa.gov/data-access-viewer/

Peter, M. (2006). Unkind cuts for incense. *Nature*, 444, 829

Article DOI: https://doi.org/10.37284/eajfa.6.1.1334

Semegnew, T., Mulugeta L., Brehane M., Galgalo, D. & Prema K. (2016). Effect of tapping intensity and tree diameter on gum arabic yield of *Acacia senegal* (L) Wild in Southern Ethiopia. *World Journal of Pharmaceutical and Life Sciences*, 2(2), 229-238.

Tadesse, W., Desalegn, G. & Alia R. (2007). Natural gum and resin-bearing species of Ethiopia and their potential applications. *Forest Systems*, 16(3),211-221.

Tadesse, W., Feleke, S. & Eshete, T. (2004). Comparative study of traditional and new tapping method on frankincense yield of *Boswellia papyrifera*. *Ethiopian Journal of Natural Resources*, 6, 287-299.

Teshome, D., Sori, T., Sacchini, F. & Wieland, B. (2019). Epidemiological investigations of contagious caprine pleuropneumonia in selected districts of Borana zone, Southern Oromia, Ethiopia. *Tropical Anim. Health Prod.,* 51 (3),703–711.

WBISPP (Woody Biomass Inventory and Strategic Planning Project). (2005). Forest resources of Ethiopia. Ministry of agriculture and rural development. Addis Ababa.

Wekesa, C., Makenzi, P., Chikamai, N., Lelon, K., Luvanda, M. & Muga M. (2009). Gum arabic yield in different varieties of *Acacia senegal* (L.) Willd in Kenya. *African Journal of Plant Science*, 3(11), 263-276.

Yasin, M. & Salah, S. (2014). The role of indigenous gums and resins in pastoralists livelihood security and climate change adaptation in Garba tula area of Northern Kenya. Agricultures Consortium as Part of the Early Career Fellowship Programmed, Brighton, UK. Future.