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Research Article

Tapping Practices, Tree Attributes, and Frankincense Yield in a *Boswellia papyrifera* Plantation in Jebel Elgarrie Natural Forest Reserve - Southeastern Sudan

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Abstract

We conducted this research in a 10-ha *Boswellia papyrifera* plantation established in 1972 in Jebel El Garrie Natural Forest Reserve (JENFR) in southeastern Sudan. We aimed at evaluating the tapping regime and assessing yield of Frankincense. We randomly distributed thirty-three circular sample plots (0.10 ha each) in which we measured diameter at breast height (DBH)(cm) and bole height (m) of trees. From within these plots, we randomly selected 87 trees to record tapping height (m) and quantify frankincense yield (g). In addition, we examined 165 tapping incisions made on 23 subset of randomly selected trees, measured their width, length, and depth, and calculated their frequency per tree, across DBH classes, and by tapping direction. We examined Pearson correlation between tree DBH and mean frankincense yield and assessed differences in mean numbers of tapping incisions among tapping directions using one-way Analysis of Variance (ANOVA). Results showed that DBH values of *B. papyrifera* ranged from 10 to 32cm, with a mean of 21.8(±6.5)cm, and bole height varied between 1.4 and 6.0m, averaging 3.0(±0.8)m. Mean tapping upper and lower heights were 1.7(±0.2m) and 0.6(± 0.2m), and the average untapped portion of the bole constituted 41.1% of the total bole height. Mean tapping intensity was 7.4(±2.8), with incision frequency increasing with DBH. Mean end-of season width, length and depth were 4.1(±1.4)cm, 3.4(±2.3)cm, and 3.5(±1.3)mm, respectively. Approximately 9.2% of all trees, including 1.1% of first-time tapped individuals, were tapped below the recommended tapping lower height of 0.5m, while only 49.1% of trees in the small DBH classes were tapped on the prescribed east and west orientations. The mean annual frankincense yield (g/tree/year) was 100.8(±70.7), increasing steadily with DBH and peaking at 130.8(±81.5)g in the 25–29.9 cm DBH class before declining in larger DBH classes. These findings underscore the need for stricter adherence to size-specific and direction-specific tapping guidelines to reduce physiological stress and improve long-term productivity of *B. papyrifera* populations.

Keywords

Resin Harvesting, Tapping Intensit, Boswellia Papyrifera, Plantation, Sudan

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1. Introduction

The genus *Boswellia* Roxb. ex Colebr. (Burseraceae) comprises about 24 species of small to medium-sized trees native to the arid regions of the Arabian Peninsula, East Africa, and India [1, 2]. Among them, *B. papyrifera* (Del.) Hochst. is a deciduous dryland species widely distributed in Ethiopia, Eritrea, and Sudan, where it is recognized for its ecological and economic importance [3]. It is the only naturally occurring *Boswellia* species in Sudan [4], extending across dryland areas south of latitude 14° N, including Jebel El Garri, the Ingasana Hills, and areas bordering Ethiopia in Blue Nile State [5].

Boswellia papyrifera trees generally become suitable for tapping at 8–10 years of age when they attain a minimum diameter at breast height (DBH) of 10–12cm [6]. It produces frankincense, an oleo-gum resin valued worldwide for its aromatic, medicinal, and religious uses [7, 8]. Although resin may exude naturally under environmental stress [9, 10], commercial production relies on tapping, a process involving deliberate and controlled wounding of a tree's bark and underlying tissues, using a specific tapping tool called Mengaf, to stimulate the exudation of resin flow as part of the tree's defense response [11, 12]. The resin hardens upon exposure to air and is collected in successive harvesting rounds [11-13]. Sustainable harvesting depends on appropriate tapping techniques, timing, intensity, and secure resource management arrangements [14].

Natural populations *B. papyrifera* across the Horn of Africa are declining due to over-tapping, fire outbreak, grazing pressure, and poor regeneration. Consequently, managed plantations are increasingly promoted to ensure sustainable frankincense production through regulated tapping, improved protection, and enhanced regeneration [8].

In Sudan, *B. papyrifera* forests are managed primarily for frankincense production while contributing to environmental protection objectives [15]. Current regulations permit tapping only on trees with a DBH of ≥10cm to support sustainable resin harvesting [16], however. important components of the tapping regime—including minimum tapping DBH, tapping height, tapping intensity and direction, incision dimensions, harvesting rounds, and resin yield—remain poorly documented in plantation settings. This study addresses this knowledge gap by evaluating the prevailing tapping regime and assessing frankincense yield in *B. papyrifera* plantations. The research provides valuable insights on characteristics of tapping regime for frankincense production and empirical results on yield from *B. papyrifera* plantations. Overall, the study concludes that although harvesting practices generally follow the prescribed seasonal calendar and tapping intensity is broadly aligned with recommendations, current management practices limit production potential. Improved adherence to tapping guidelines, better tapping techniques, and sustainable harvesting practices are required to enhance frankincense yield while maintaining the long-term health and productivity of *B. papyrifera* plantations.

2. Materials and Methods

2.1. Boswellia Papyrifera Plantation

The Forest Research Centre (FRC) in Sudan established a 10-ha *B. papyrifera* plantation within the Jebel Elgarrie Natural Forest Reserve (JENFR; 11°46′–11°50′ N, 34°36′–34°42′ E) in Blue Nile State during the early 1970s using vegetative propagation from branch cuttings. Each cutting was planted in a pit 45–90cm deep with an approximate cross-sectional area of 900cm^2 [17]. The plantation was laid out at a uniform spacing of 2m×2m. It supports a simplified but structured woody plant community, where *B. papyrifera* dominates the canopy while associated species contribute to understory diversity [18] (Figure 1).

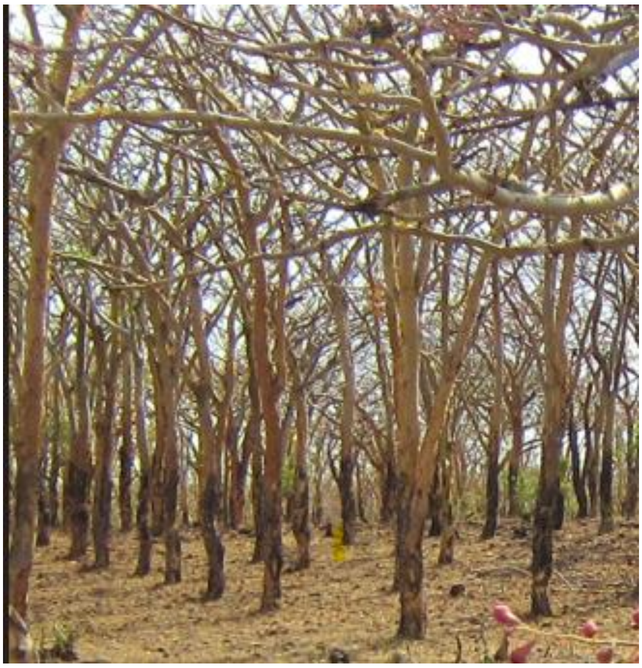

Figure 1. *Boswellia papyrifera plantation at Jebel Elgarrie Natural Forest Reserve.*

2.2. Data Collection

2.2.1. Diameter at Breast Height and Bole Height

We randomly established 33 circular sample plots (0.10 ha each) across the study area. Within each plot, we sequentially tallied all tapped *B. papyrifera* trees, measured DBH (cm) using a caliper, and determined bole height (m) with a clinometer. We then classified all tapped trees into five fixed DBH classes (10–14.9, 15–19.9, 20–24.9, 25–29.9, and 30–34.9 cm).

2.2.2. Tapping Heights

We applied a stratified random sampling approach based on

DBH classes to select tapped *B. papyrifera* trees for analyzing tapping heights. Within each DBH class, we assigned unique identification numbers to all trees and selected individuals by simple random sampling to ensure representative coverage across the diameter range. This procedure yielded a total of 87 sampled trees, distributed among the five DBH classes at 15, 20, 18, 19, and 15 trees, respectively. For each sampled tree, we measured the tapping lower height (TLht) (m) and tapping upper height (TUht) (m) using a measuring tape. We then calculated the untapped bole height (UTbht) (m) as the difference between the total bole height (m) and the TUht (m).

2.2.3. Number, Direction, and Dimensions of Tapping Incisions

We examined a total of 165 tapping incisions from a randomly selected subset of 23 of the 87 sampled trees. For each incision, we measured width, length, and depth. We also recorded the total number of tapping incisions per tree, and summarized incision frequencies by DBH class and tapping direction.

2.2.4 Frankincense Yield

We determined frankincense yield for the same 87 sampled trees. Resin collected from each tree during successive tapping rounds was air-dried in the field for two weeks and then weighed using a digital analytical balance with a precision of 0.01 g. We calculated annual frankincense yield (g/tree/year) as the cumulative resin mass obtained from all tapping rounds during the tapping season. We evaluated the relationship between DBH and annual frankincense yield using Pearson's correlation analysis ($\alpha = 0.01$, two-tailed), and tested differences in the mean number of tapping incisions among tapping directions using one-way analysis of variance (ANOVA) at $\alpha = 0.01$.

3. Results

3.1. Tenure and Harvesting Season of *Boswellia papyrifera* Plantation

The *B.* plantation forms part of JENFR, which, under the Forests and Renewable Natural Resources Act [19], is designated as state property and classified as a central forest reserve. As such, it falls under the technical and administrative authority of the Forest National Corporation (FNC), the national forest service in Sudan, which holds full legal jurisdiction over the resource. Consequently, both land and tree tenures within the reserve are formally secured.

Findings indicated that the harvesting of *B. papyrifera* for frankincense production during the study season began in September, tapping process started in October, and collection of resin started in January and continued until April of the following year. Tapping was conducted in four successive rounds, during which the initial incisions were refreshed and progressively enlarged at each tapping.

3.2. Tree Attributes

3.2.1. Diameter at Breast Height (DBH) and Bole Height

Observed values of DBH of frankincense-producing *B. papyrifera* ranged from 10 to 32cm, with a mean of 21.8(±6.5)cm. Trees were relatively evenly distributed across five DBH classes where 18.4%, 23.0%, 20.7%, 21.8% and 16.1% of individuals were accommodated in the 10–14.9, 15–19.9, 20–24.9, 25–29.9, and 30–34.9cm DBH classes, respectively. While bole height measurements ranged from 1.4 to 6.0m, the pooled mean bole height was 3.0 (±0.8)m. Most trees (78.2%) fell within the 2.0–3.2m bole height class interval, reflecting a narrow distribution around the central tendency.

3.2.2. Tapping Heights

TUht ranged from 1.2 to 2.1m, with a mean of 1.7(± 0.2)m, while TLht ranged from 0.2 to 1.4m and averaged 0.6(± 0.2)m. About 9.2% of trees, distributed across almost all DBH classes, were tapped at heights lower than the prescribed 0.5 m tapping lower height threshold. UTbht showed the greatest variability, extending from 0.0 to 4.25 m, with a mean of 1.2(± 0.8)m, corresponding to 41.1% of the mean total bole height.

3.2.3. Number, Direction, and Dimensions of Tapping Incisions

Across all sampled trees, the total number of tapping incisions applied per tree per year ranged from 2 to 15, with a mean of 7.2(±2.1). The mean numbers of tapping incisions per DBH class were 5.7(±1.8), 6.1(±1.7), 7.7(±1.9), 8.3(±2.9), and 9.3(±3.8) for trees within the 10–14.9, 15–19.9, 20–24.9, 25–29.9, and 30–34.9cm DBH classes, respectively (Figure 2). Statistical analysis revealed a significant correlation ($r=0.48$, $p= 0.000$) between tree DBH and number of tapping incisions. Results showed that trees across all DBH classes were tapped in all four directions. Total numbers of tapping incisions in a season, made on the 23 randomly selected trees, were 47, 50, 31, and 37 made at North, East, West and South directions, respectively (Figure 3). A one-way ANOVA showed no significant difference in the mean numbers of incisions among tapping directions ($F = 0.435$, $p = 0.728$).

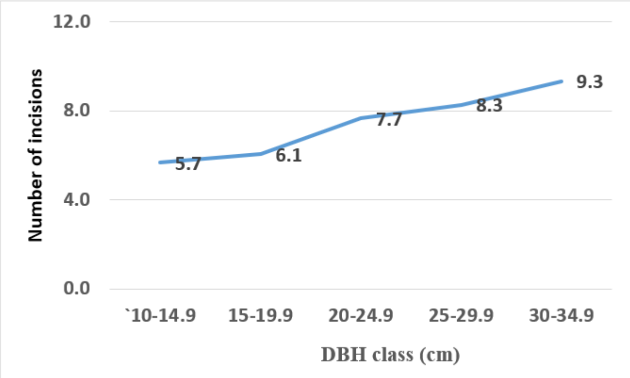

Figure 2. *Number of tapping incisions per DBH classes.*

Initial width, length, and depth measurements of the tapping incisions at the beginning of the season had minimum values of 1cm, 1cm, and 1mm, while the maximum values reached 19cm, 12cm, and 7mm, respectively. Across all sampled incisions (N = 165), the end-of-season mean dimensions were 4.1(±1.4)cm, 3.4(±2.3)cm, and 3.5(± 1.3)mm for width, length, and depth, respectively.

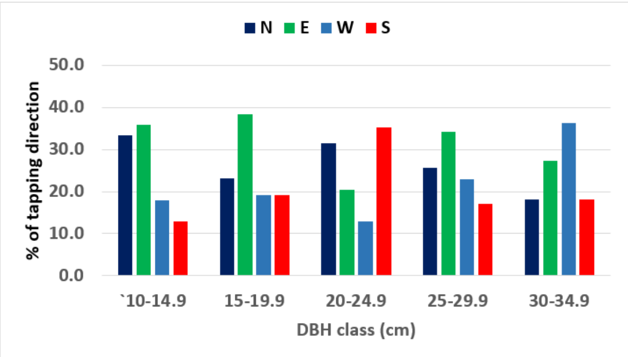

Figure 3. *Percentage of direction of tapping incision.*

3.2.4. Frankincense Yield

Total frankincense yield (g/tree/year) collected from the four tapping rounds in the plantation during the assessment season ranged from 2.3 to 344.0g, with a mean of 100.8(±70.7)g. Zero yields were recorded for 20, 13, 18, and 6 trees distributed across the five DBH classes during the four successive collections. Yield increases progressively from 56.8 g/tree/year in the smallest class (10–14.9cm) through intermediate sizes, peaking in the 25–29.9cm class at 130.8 g/tree/year and declined thereafter (Figure 4). Mean frankincense yield was positively significantly correlated with DBH class (r=0.29, P=0.006).

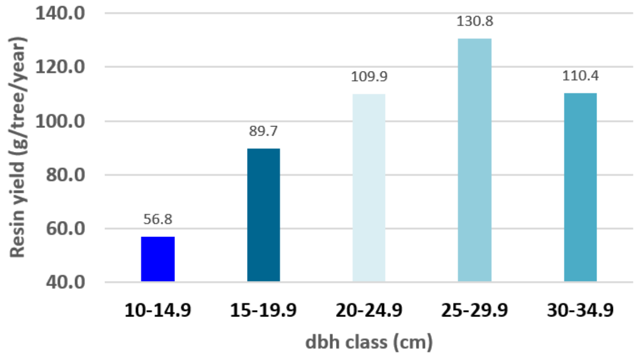

Figure 4. *Trend of mean frankincense yield across DBH classes in plantation forests.*

4. Discussion

4.1. Tenure and Harvesting Season of *Boswellia papyrifera* Plantation

Actively tapped species generally have much stronger land tenure systems in place than do untapped species because of the energy investment in tapping [20]. Forest-sector reforms in Sudan, particularly those introduced under the Forests and Renewable Natural Resources Act (2002) [19] strengthen regulated access and long-term use rights, thereby reducing resource-related conflicts and improving governance. The *B. papyrifera* plantation forms an integral part of JEFNR, which is legally designated as state property under the 2002 Act. This designation prioritizes national ecological and economic interests and provides the reserve with the highest level of protection through strict regulation of land use, harvesting, and conversion. Secure land tenure is essential for sustaining tree-based production where farmers with recognized and enforceable rights are more willing to manage natural trees and invest in planting [21].

Each *Boswellia* species has a distinct season considered optimal for resin collection, typically lasting 3–6 months during the dry period [20]. The harvesting season of frankincense as in JENFR commences by producers' gaining legal access to *B. papyrifera* forest land through production permits provided by the FNC for a fee, usually during September to mark the start of harvesting season that ends by June of the following year [16]. Tapping begins in October, whereas frankincense collection starts in January and continues through April of the following year, ending earlier than the usual season, which typically extends into June. Nevertheless, these activities remain within the prescribed harvesting window for the Blue Nile region in Sudan [22, 23].

4.2. Tree Attributes

4.2.1. Diameter at Breast Height and Bole Height

The DBH distribution in the frankincense-producing *B. papyrifera* plantation indicates a moderate spread of tree sizes. The plantation exhibits a smaller mean DBH of 21.8 (±6.5)cm compared with 25.7(±7.3)cm in JENFR and 28.9(±7.4) cm in the adjacent Abugadaf Natural Forest Reserve (AGNFR) [15]. Its maximum DBH of 32 cm is also notably lower than the 44 cm recorded in JENFR [16] and the 51.0 cm reported for AGNFR [15]. Despite these differences, the plantation's size structure aligns well with cutting-based *B. papyrifera* plantations in Ethiopia, where thirteen-year-old stands typically attain DBH values ranging from 14 to 23.5 cm. Compared with natural forests, *B. papyrifera* plantations generally exhibit a narrower diameter-size distribution and tend to show greater structural uniformity than natural forests, where trees are distributed across a broader range of diameter classes and age cohorts [24].

The pooled mean bole height of 3.0(±0.8)m in the plantation is shorter than the 3.5(±1.1) m reported for JENFR. Likewise, the proportion of untapped bole height is comparatively lower where only 41.1% of the bole height in the plantation remains untapped, compared with 49.7% in JENFR [16] and 45.5% in AGNFR [15]. Despite being smaller, this proportion still represents a substantial section of the upper bole that retains full utility value. Improving tapping techniques to safely reach higher positions, while accounting for tree diameter, would enhance the vertical distribution of tapping points without necessarily increasing the total number of incisions [16]. It is customary practice to place new tapping spots above old ones made in previous seasons [13, 25-27] leading to an upward shift in tapping height. Expanding the tapping area vertically above old tap holes increases the likelihood of encountering fresh conductive wood and provides additional time for wood growth over previous wounds, thereby reducing the risk of re-tapping compartmentalized tissue [28].

4.2.2. Tapping Heights

The mean TUht of 1.7(± 0.2)m and TLht of 0.6(± 0.2)m in the plantation closely match values reported for the JENFR of 1.8(± 0.2)m and 0.7(± 0.1)m, respectively [16], as well as those recorded in the AGNFR of 1.8(±0.13)m and 0.64(±0.15)m [15]. The maximum tapping height observed in the plantation reached 2.1m, indicating that tappers occasionally access higher bole positions beyond the mean TUht. In the current tapping practice in Sudan, the tree's height is not a determinant factor for the number of wounds since the laborers tap into the reachable parts of the trees [29]. The traditional practice of tapping requires innovative techniques to reach higher parts to maximize the use of bole height [15].

Approximately 9.2% of all trees are tapped below the recommended minimum tapping height of 0.5m, with nearly half of these trees belonging to the two smallest DBH classes, and only 49.1% of trees were tapped on the prescribed east and west orientations. Together, these patterns indicate substantial departures from established tapping guidelines, particularly for smaller trees that require more conservative harvesting practices.

4.2.3. Number, Direction, and Dimensions of Tapping Incisions

The total number of tapping incisions applied per tree per year ranged from 2 to 15. This range is broadly consistent with earlier findings on tapping intensity in natural *Boswellia* woodlands, including 6–10 [29] and 6–12 [22] in southeastern Sudan; 6–15 in western Sudan [30]; 3–16 [20, 32], 8-12 [31] and 6–16 [13] in Ethiopia.

The results demonstrate that tapping practices are strongly size dependent, with the mean number of incisions increasing progressively with tree diameter. This pattern is consistent with previous studies showing that the number of tapping incisions is largely determined by tree size, as larger trees provide greater surface area for wound placement [1, 20, 33].

Tapping intensity across the different DBH classes in this study conforms to recommended guidelines [13], with mean values of six incisions for the two smallest classes, eight for the medium classes, and nine for trees larger than 30 cm. This distribution closely matches patterns reported in JENFR [16], where mean incision numbers are 6 for small trees (10–14.9 and 15–19.9 cm), 8 for medium trees (20–24.9 and 25–29.9 cm), and 12 for large trees (30–34.9, 35–39.9, and 40–44.9 cm). However, the practice of intensive tapping trees with small DBH reflects a management approach driven more by short-term resin extraction than by ecological sustainability [34]. Recent tapping practices have intensified overall, as evidenced by the increasing number and size of wounds, which has caused substantial damage to many *B. papyrifera* trees and contributed to reduced viable seed production [1]. Applying an optimum tapping intensity is therefore essential to maintain an appropriate balance between tree size, total frankincense yield, and the long-term health and productivity of the trees [13].

A one-way ANOVA showed no significant difference in the mean numbers of incisions among the four tapping directions. This uniformity in incision numbers indicates a clear departure from recommended harvesting practices. In the field, first-time-tapped and small-DBH trees are being tapped on all sides in the same manner as larger trees. Such practice contradicts established guidelines, which specify that tapping of small-sized trees should be restricted exclusively to the east and west sides to minimize physiological stress and reduce mortality risk. The significance of tapping *B. papyrifera* on the east and west sides is grounded in experimental evidence showing that tapping toward sunlight increases resin yield. [22] demonstrated that tapping direction has a highly significant effect on resin production, and that east–west orientations—i.e., the sides receiving morning and afternoon sunlight—produce higher yields than other directions. This supports the physiological explanation that moderate sunlight exposure warms the bark, stimulates resin exudation, and avoids the overheating or excessive moisture associated with south- and north-facing sides.

Findings from previous studies show substantial variation in the dimensions of tapping incisions created using the *Mengaf* across various locations. Reported initial measurements of incision width, length, and depth range from 0.4–4.0 cm, 1.0–3.0 cm, and 0.5–5.0 mm, respectively [9, 13, 22, 23, 25, 26, 34]. The mean incision dimensions observed in the plantation generally fall within these previously reported ranges, indicating broad agreement with earlier findings.

The end-of-season dimensions of tapping incisions on *B. papyrifera* plantation trees averaged 3.4(±2.3)cm in width, 4.1(±1.4)cm in length, and 3.5(±1.3)mm in depth. These values closely match those reported for JENFR—3.5(±0.9)cm, 4.3(±1.5)cm, and 3.5(±1.2)mm, respectively [16], are smaller than the corresponding dimensions recorded in AGNFR, which averaged 4.6 (±1.3)cm, 6.6 (±2.5)cm, and 4.3 (±1.6)mm [15], and markedly lower than the much larger 6cm, 10cm, and approximately 10–20mm values documented by [26] and [13].

4.2.4. Frankincense Yield

Earlier studies report substantial variability in annual frankincense yield per tree, reflecting the influence of multiple ecological and management factors. Key determinants include tree size and diameter, tapping height, and resting time between tapping rounds [7], as well as site productivity and seasonal conditions and wound recovery [26]. Variations in tapping practices and inherent differences in the metabolic activity of individual trees contribute to the observed yield fluctuations [35].

This study shows that the mean frankincense yield (g/tree/year) in the JENFR plantation is considerably lower than the 1318.87 (±54.11 g) reported for first-time tapped, 14-year-old cutting-based plantations in Ethiopia [24]. It is also lower than 600 g [29]; 288.5 g at lower altitudes and 250.5 g at higher altitudes [22]; and 145.8 (±115.2) [16] previously reported in JENFR and below the 1700–2600 g [5], 655–1000 g [36] in South Kordofan, and 2800 g in Jebel Marra [37].

The trend of mean frankincense yield shows a clear increase with DBH, rising to a maximum of 130.8 g/tree/year in the 25–29.9 cm class before leveling off, a pattern consistent with observations from natural Boswellia forests. However, the slight decline to 110.4 in the 30–34.9cm class suggests a threshold beyond which frankincense output may level or diminish. These results align with previous studies on resin yield of natural forests of *B. papyrifera* [24, 26, 45] where yield (g/tree/year) average approximately 328, 469, and 809 for trees in the 10–15cm, 16–20cm, and >20cm DBH classes, respectively. This pattern highlights the importance of targeting mid-sized mature trees for sustainable frankincense harvesting, balancing productivity with long-term forest health.

The absence of resin production in some tapped *B. papyrifera* trees across tapping rounds and/or DBH classes may be attributed to several interacting factors, including depletion of stored resin after repeated tapping, low carbohydrate reserves, excessive tapping intensity, continuous tapping without adequate resting periods, variation in resin canal anatomy, wound healing, environmental stress, and pest or disease damage [3, 7, 26, 33].

The strong positive relationship between trunk size and frankincense yield observed in this study aligns with earlier findings that larger *Boswellia* trees possess thicker stems, thicker inner bark, and a greater inner-bark surface area, all of which contribute to a higher density and total area of resin canals. These anatomical advantages enable larger individuals to produce more resin than smaller trees, consistent with the broader ecological link between tree size and carbon storage capacity [38-40]. Their greater carbon reserves and enhanced metabolic capacity also facilitate increased allocation to resin synthesis following tapping [41]. This interpretation is supported by [42], who reported higher frankincense yields in larger trees due to more extensive resin-canal development. At the physiological scale, resin production is not driven by radial growth rate but instead increases with total resin-canal area, stem diameter, tree age, and the number of leaf apices [43], reinforcing the vital role of tree size and internal anatomy in determining yield potential.

The extraction of oleo-gum-resins has evolved from traditional manual tapping techniques to modern methods such as supercritical fluid extraction, microwave-assisted extraction, and ultrasound-assisted extraction, enhancing yield and purity [44]. In the Horn of Africa, trees of dry tropical forests that produce resin that is used as frankincense lack sophisticated, commercialized, sustainable harvest systems [26]. The resin yield of *B. papyrifera* can be improved by modifying the tapping techniques [45, 46], tools, and skills [16, 47], and updating tapping and collection techniques to ensure long-term tree survival [21]. Recommended improvements include adopting less strenuous approaches—such as incorporating rest periods between tapping cycles, reducing the number of tapping points per tree, and lowering tapping frequency within each season [6].

5. Conclusion

This study demonstrated that frankincense production in the *B. papyrifera* plantation of JENFR is characterized by secure tenure arrangements and harvesting practices that generally follow the regional tapping calendar. Tree diameter significantly influenced both tapping intensity and resin yield, with larger trees receiving more tapping incisions and producing higher yields. However, departures from recommended tapping guidelines were observed, including tapping of small trees, low tapping heights, and indiscriminate use of all stem orientations. Mean frankincense yield was relatively low compared with yields reported from natural forests and managed plantations elsewhere, suggesting limitations associated with current tapping practices, tree size structure, and plantation productivity.

The findings suggest that while current harvesting practices are broadly acceptable, improvements in tapping techniques and adherence to management guidelines are needed to enhance resin yield and ensure the long-term sustainability of *B. papyrifera* plantations.

Abbreviations

JENFR	Jebel Elgarrie Natural Forest Reserve
AGNFR	Abugadaf Natural Forest Reserve
DBH	Diameter at Breast Height
TUht	Tapping Upper Height
TLht	Tapping Lower Height

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Author Contributions

Dafa-Alla Mohamed Dafa-Alla Ahmed: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – original draft

Kamal Eldin Mohammed Fadul: Writing – review & editing

Hashim Adam Abdelkarim: Data curation, Project administration

Data Availability Statement

The original data upon which this manuscript has been prepared is readily available on request from the main author Dafa-Alla M. D. Ahmed.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Dafa-Alla Mohamed Dafa-Alla Ahmed is an Associate Professor of Forest Economics at the Faculty of Forestry, University of Khartoum. He holds B. Sc.(Forestry) from the University of Juba, M. Sc. (Tropical Forestry) from Wageningen Agricultural University, and Ph. D. (Forestry) from the University of Khartoum. With over four decades of experience in forestry research and management, his work focuses on forest economics, valuation of non-wood forest products, sustainable forest management, and environmental conservation. He has published widely and led numerous national research and consultancy projects.

Research field

Dafa-Alla Mohamed Dafa-Alla Ahmed: Forest management economics, valuation of forest ecosystem goods and services, non-timber forest products value chains, windbreaks, Frankincense production and economics.

Kamal Eldin Mohamed Fadul: Gum Arabic, Frankincense, silviculture, climate change.

Ha shim Adam Abdelkarim: Forest management, Hyphaene thebaica, climate change, socioeconomic.