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Research article

Continuous resin tapping for frankincense harvest increases susceptibility of *Boswellia papyrifera* (Del.) Hochst trees to longhorn beetle damage

Aklilu Negussie [a,*], Kindeya Gebrehiwot [b], Mekonnen Yohannes [c], Lindsey Norgrove [d], Ermias Aynekulu [e]

[a] WeForest, P.O. Box 25450/1000, Addis Ababa, Ethiopia
[b] Land Resources Management and Environmental Protection Department, Mekelle University, P.O. Box 231, Mekelle, Ethiopia
[c] College of Health Sciences, Mekelle University, P.O. Box 231, Mekelle, Ethiopia
[d] Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences, 3052 Zollikofen, Switzerland
[e] World Agroforestry (ICRAF), United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya

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ABSTRACT

Frankincense is an important tree resin that provides a livelihood in the semi-arid lower highlands of East Africa. In the absence of sustainable management strategies, *Boswellia papyrifera* trees were being overexploited, leading to a depletion of genetic diversity, affected by pests and diseases, failure in natural regeneration, and hence a subsequent decline in socio-ecological benefits obtained from the species. We studied the impact of (i) continuous resin tapping without resting years and (ii) tapping or wonding intensity for frankincence production on the prevalence of longhorn beetle (*Idactus spinipennis* Gahan, Cerambycidae (sub family Lamiinae) damage in northern Ethiopia. We found that continuous resin tapping for frankincense harvest without adequate resting period made trees more vulnerable to longhorn beetle damage ($P < 0.05$). Trees rested for 10 and more years from resin tapping had less beetle damage occurrence than those tapped continuously ($P < 0.05$). Stem tapping intensity of more than 12 wounds per tree in one frankincense harvesting season caused high longhorn beetle damage incidence in Central Tigray (up to 90%) and Western Tigray (up to 80%). We recommend that *B. papyrifera* trees should have a resting period of at least 3 years and more after one year of continuous tapping. Depending on the size of a tree, wounding for frankincense harvest should be restricted to less than 12 wounds per tree. These measures would help the species develop resistance to longhorn beetle attack and maintain a healthy population for sustainable provision of ecosystem services including frankincense production in the dryalnds of northern Ethiopia.

1. Introduction

Boswellia papyrifera (Del.) Hochst (frankincense tree) is a deciduous tree up to 12 m height (Lemenih and Teketay, 2003). Its main product, frankincense, has a long history in human civilization and is an internationally valued product for several uses in industries and ritual services (Gebrehiwot et al., 2003; Lemenih and Teketay, 2003; Negussie et al., 2008). However, the tree population has declined due to human pressure (e.g., agricultural land expansion, over tapping, and overgrazing) and natural factors including fire and insect infestation and damage (Ogbazghi et al., 2006; Lemenih et al., 2007; Negussie et al., 2008, 2009, 2018).

In the northern drylands of Ethiopia, *Boswellia papyrifera* (Del.) Hochst woodlands, used for frankincense extraction, are facing habitat fragmentation, threatening ecosystem health (Aynekulu et al., 2016; Negussie et al., 2018). However, frankincense production in northern Ethiopia has not been sustainable (Mekonnen et al., 2013). In Ethiopia, estimated annual production potential of gum and resin was more than 300,000 tonnes, although to date the country produces less than 1% of its potential (Mekonnen et al., 2013).

Boswellia papyrifera habitats have been deforested for agriculture and new settlements. The remaining stands were found on geographically inaccessible and marginal areas for cultivation and grazing. In addition, the rapid spread of pests and diseases due to mismanagement (e.g., continuous resin tapping without enough resting period and wounding

* Corresponding author.
E-mail address: aklilumekuria@weforest.org (A. Negussie).

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intensity, free grazing, and change in forest land use to other purposes) and land degradation has led to severe environmental deterioration and mortality of *B. papyrifera* trees. Studies have reported how wood-boring insects can cause structural and functional disruption of primary and secondary growth of the trees and lead to tree mortality (Filion et al., 1998; Moore and Allard, 2011; Fischer et al., 2013), reduce frankincense productivity (Eshete et al., 2012; Negussie et al., 2018), reduce carbon stocks and thus affect the resilience potential of those societies depend on tree products (Dale et al., 2001; Lemenih et al., 2007; Mekonnen et al., 2013).

The longhorn beetle, *Idactus spinipennis* Gahan, Cerambycidae (sub family Lamiinae) in the dry lowlands of northern Ethiopia is becoming a serious pest of frankincense and other gum- and resin-bearing trees such as *Commiphora africana* (A. Rich.) Engl. and *Lannea fruticosa* (Hochst.) Engl. (Negussie et al., 2018). The presence of and damage by *I. spinipennis* in Boswellia woodlands was first reported by Negussie (2008) who observed up to 87% insect infestation and damage of *B. papyrifera* in Central Tigray. Similarly, Negussie et al. (2018) observed annual rates of *B. papyrifera* tree mortality caused by *I. spinipennis* to be as high as 8% in Western Tigray and 7% in Central Tigray. Similarly, an unknown longhorn beetle from the Cerambycidae family caused damage to *Acacia senegal* (L.) Willd. and *A. seyal* Del. gum-producing trees in Sudan (Eisa and Adam, 2010).

Frankincense is produced by making incisions around the trunk of the tree (Figure 1) during the dry season (September to June). Traditionally, incense collection is prohibited during the rainy season (July and August), because of low harvest and poor quality. At other times, 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).

In the dry lowlands of northern Ethiopia, frankincense provides off-farm employment, particularly during poor agricultural production years (Mekonnen et al., 2013). Poor tapping management and continuous frankincense collection may damage *B. papyrifera* trees and increase the risk of insect infestation and damage. Previous research also suggested that longhorn beetle damage was greater in frankincense trees that were tapped too frequently or intensively (Negussie, 2008; Eshete et al., 2012). Therefore, this study investigated the impact of (i) continuous resin tapping without resting years and (ii) tapping or wonding intensity for frankincence production on the prevalence of longhorn beetle (*Idactus spinipennis* Gahan, Cerambycidae (sub family Lamiinae) damage in northern Ethiopia.

Figure 1. Local farmer tapping *Boswellia papyrifera* tree for frankincense collection in Jijike, Central Tigray. Photo taken by Aklilu Negussie.

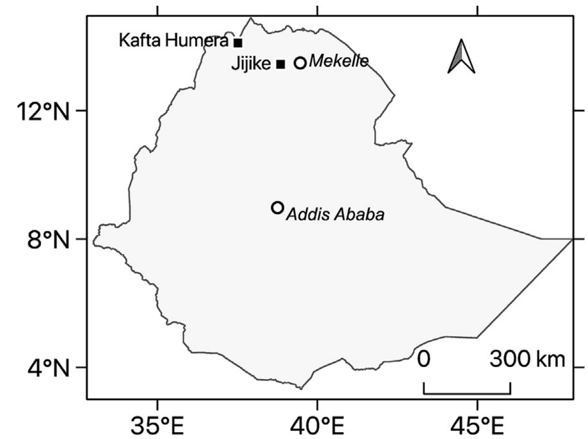

Figure 2. Study site locations.

2. Materials and methods

2.1. Study area

Two Boswellia habitats were selected in northern Ethiopia (Figure 2). The first site, Kafta Humera, is located at 14° 07′ N 37° 31′ E at an altitudinal range of 560–1849 m.a.s.l. in Western Tigray (Gebrehiwot et al., 2016; Negussie et al., 2018). Mean annual rainfall is 581 mm and the rainy season is from June–August. Mean annual temperature is 28.5 °C with minimum and maximum mean temperatures of 20.2 °C and 41.7 °C, respectively (Gebrehiwot et al., 2016; Negussie et al., 2018).

The second site, Jijike, is located at 13° 27′ N 38° 51′E and at an altitudinal range of 1400–1650 m.a.s.l. in Central Tigray (Negussie et al., 2018). Mean annual rainfall is 657 mm, most of which occurs between June and August. Mean annual temperature is 22.3 °C with minimum and maximum mean temperatures of 20 °C and 31.3 °C (Gebrehiwot et al., 2016; Negussie et al., 2018).

In both sites, the forest has been fragmented due to subsistence agriculture, livestock grazing (mainly cattle, goat, sheep, donkey and camel), and has been over-harvested for fuelwood and frankincense collection (Negussie et al., 2018). *Boswellia papyrifera* was the dominant tree species in both sites with average stand density of 403 and 402 trees/ha, respectively, in Kafta Humera and Jijike sites and the highest diameter frequencies ranged from 15–25 cm. No trees were recorded in

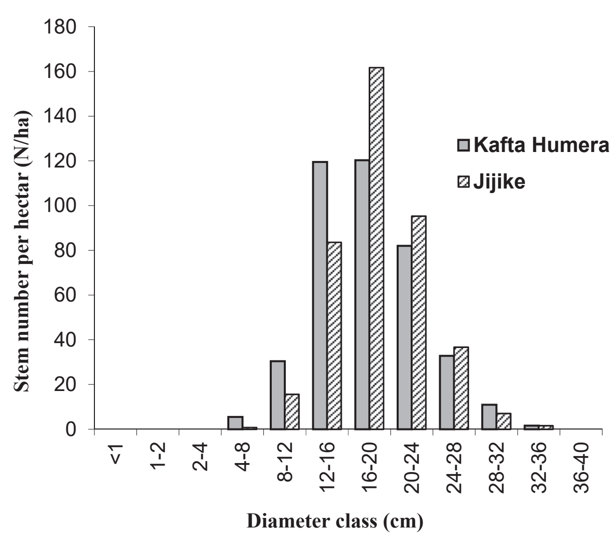

Figure 3. Population structure of *Boswellia papyrifera* in Kafta Humera in Western Tigray and Jijike in Central Tigray, Northern Ethiopia.

the size classes below 7.5 and above 36 cm in Jijike and below 5 and above 36 cm in Kafta Humera (Figure 3). Tree species such as *Acacia etbaica* Schweinf., *Terminalia brownii* Fresen., *Dichrostachys cinerea* (L.) Wight & Arn, *Anogeissus leiocarpus* (DC.) Guill. & Perr., *Combretum hartmannianum* Schweinf., *Combretum fragrans* F. Hoffm and *Lannea fruticosa* Engl. are also very common in both sites.

2.2. Longhorn beetle species description

As described by Negussie et al. (2018), the longhorn beetle (*Idactus spinipennis* Gahan) is in the family of Cerambycidae (sub family Lamiinae). It is light gray on the head and ivory colour in the middle of its elytron. Body size of the adult measured 1.3 cm length and 0.3 cm width with long antenna 1.5 cm (Negussie et al., 2018). The long white destructive larva can stay up to 10 months inside the tree before pupation and dispersal. The larvae bore into the stem and branches of Boswellia trees and cause physiological disturbance and sometimes complete mortality of trees (Negussie et al., 2018).

2.3. Data collection

2.3.1. Resting period and longhorn beetle damage

The main study was conducted from 2005 to 2009 and additional information was collected in 2015 and 2016. We evaluated different management strategies, comparing stands of *B. papyrifera* that had been tapped and untapped for different periods, to assess the relationship between tapping frequency and longhorn beetle damage. Different *B. papyrifera* woodland patches in Kafta Humera and Jijike were selected based on their resin tapping management history for frankincense collection. For Kafta Humera, Western Tigray annually tapped without rest; rested for 3 years; rested for 10 years; and Boswellia woodlands left untapped for more than 10 years were considered. In Jijike, Central Tigray, however, we could only find annually tapped trees and those rested for 2.5 years, so longer rest treatments were not considered. For each selected woodland, we sampled points every 50 m along each of two transects that were spaced 200 m apart. Total length of the transects for Kafta Humera were 1.3 km (27 points), 1.4 km (29 points), 1.65 km (34 points) and 1.35 km (28 points), respectively for sites that were frequently tapped, 3 years rested, 10 years rested and more than 10 years untapped. For Jijike, the total transect lengths were 1.65 km (34 points) for frequently tapped site and 1.5 km (31 points) for site rested for 2.5 years.

Figure 4. Adult longhorn beetle, *Idactus spinipennis* exit holes.

At each sampling point at both sites, the three nearest *B. papyrifera* trees with different diameter classes of $\leq$15 cm; $>$ 15 $\leq$ 25 cm; and $>$25 cm diameter at breast height were marked as sample trees. For each tree, we recorded the presence/absence of longhorn beetle damage, by observing the stem and crown branches for one or more signs of either the beetle exist holes with frass or of the larvae themselves in the branch or stem (Figure 4). Since counting specific adult beetles in the field is very difficult, populations and damage can be estimated by counting defined exit holes, its frass and the presence of larvae in dead or living branches of defined size category of the beetle (Collinge et al., 2001; Negussie et al., 2018). The insect is more attracted to lateral and terminal branches, which are more succulent and easier to chew (Negussie et al., 2018). Accordingly, the proportion of damaged branches was calculated by counting total lateral branches (each lateral branches with their terminal branches/twigs) based on current damage on lateral branches with one or more beetle holes, its frass and observing the larval presence.

2.3.2. Tapping intensity on B. papyrifera trees and longhorn beetle damage

We identified currently tapped trees to investigate the impact of tapping intensity, that is wounding number per tree in one tapping season on the prevalence of longhorn beetle damage. Tapping intensities on the stem were grouped based on the number of fresh wounds, i.e., from the current tapping year. The wounding intensity per tree was categorised as follows: less than 6 points, 6 points (considered as average and recommended by local farmers for mature *B. Papyrifera* trees), 7–12 points and more than 12 points. We also considered untapped trees for more than 10 years rested in Kafta Humera, Western Tigray, which were sampled from adjacent site for comparison. In total, 200 for Jijike and 250 sample trees for Kafta Humera (50 trees of each wounding intensity and the unwounded control) with diameter at breast height ranging from 15 - 26 cm were selected systematically based on the wounds made for frankincense harvest. The diameter class 15–26 cm was also abundant at both sites and represented a well-matured size for frankincense harvest (Figure 3). Occurrence of beetle damage (at least one longhorn beetle borehole with its frass sign) on stems and crowns were recorded. Numbers of beetle-damaged lateral branches with their twigs were counted and the proportion of damaged crown were calculated in percent. At the Jijike site, untapped trees were not found and only tapping intensities of at less than 6 points, 6 points, 7–12 points and more than 12 points were only considered.

2.4. Data analysis

We first conducted tests for normality (Kolmogorov–Smirnov D statistic) and equality of variance (Levene statistic) on all collected data. Since data were not normally distributed, we used non-parametric tests by ranking. Descriptive statistics such as mean percentage (Mean % $\pm$ S.E.) and frequency percentage were also used to estimate longhorn beetle damage prevalence on *B. papyrifera* trees, considering one or more beetle boreholes caused by *I. spinipennis*. We used a Mann-Whitney U test for the Jijike (only two tapping management group) and Kruskal-Wallis one-way ANOVA by ranking (explained by Kruskal-Wallis χ^2 and P value) for the Kafta Humera site (4 tapping management groups). To assess the effects of tapping intensity (wounding) and tree diameter class on longhorn beetle damage occurrence, we also used Kruskal–Wallis one-way ANOVA by ranking for both sites. Pair-wise comparisons after Kruskal–Wallis ANOVA were computed using a post hoc Dunn-Bonferroni test to determine which tapping management level or tapping intensity is significantly different from the others. Proportion of beetle damage on *B. papyrifera* crown's branch was quantified as a percentage, based on lateral branches damage count over the total branches and described using frequency graph for both tapping management and tapping intensity. Further degree of damage percent on the branches for different resting periods and wounding intensity was analysed using Kruskal-Wallis one-way ANOVA and group difference was computed using post hoc Tukey HSD pairwise comparisons test after the Kruskal-

Wallis one way ANOVA. We also looked at the relationship between tree diameter size and branch damage percent for *B. papyrifera* trees collected from different resting regimes using Spearman's rank-order correlation test. The total percentage of damaged stems by longhorn beetle were described for each tapping management level. All data were analysed in SPSS 20 for windows (SPSS Inc., Chicago, IL).

3. Results

3.1. Tapping frequency (tree resting period) and longhorn beetle damage

Tapping frequency affected longhorn beetle damage occurrence on *B. papyrifera* trees in Kafta Humera ($\chi2 = 29.559$; $P < 0.001$). Frequently tapped and less rested *B. papyrifera* trees were more vulnerable to longhorn beetle damage. Fewer trees with longhorn beetle damage were observed at sites where trees had been rested for more than 10 years (28 ± 5.0%; mean % ± S.E) than at sites with frequently (yearly) tapped trees (69 ± 5.0%) (P = < 0.001). The damages for 3 years and 10 years were (58 ± 4.9%) (P = < 0.001) and (50 ± 5.5%) (P = 0.002), respectively. Damage occurrence between 3 years' rested and annually tapped trees was not significantly different (P = 0.684).

Extent of damage on branches and stem (damage percentage frequency) was high for frequently tapped trees ($\chi2 = 44.459$; $P < 0.001$). There was less damage on branches and stems of both trees that had been rested for 10 years and those rested for more than 10 years at Kafta Humera, however, there was no significant difference in damage between the two latter groups (P = 0.537) (Figure 5a). We observed a high percentage of branch damage for both trees rested for 3 years and annually tapped without rest. These two groups showed higher damage than those rested for 10 years or more ($P < 0.05$ in all paired group cases) (Figure 5a). Total stem damage observed from sampled trees in Kafta Humera was 1.4% (the sample comprised 4 trees that had been from annually tapped and 1 tree that had been from 3 years rested for three years). Large diameter trees had more beetle damage percentage on their branches than small diameter sized trees ($\chi2 = 60.698$; $P < 0.001$) (Figure 5b). The Spearman's correlation test result was positive and significant ($r_s = 0.354$; $P < 0.001$). Trees with diameter class with ≤15 cm showed significantly less damage percentage on crown branches than those of other diameter classes ($P < 0.001$) (Figure 5b). There was no significant difference in branch and stem damage percentage between trees with diameter class >15 ≤ 25 cm; and > 25 cm (P = 0.286).

According to the Mann-Whitney U test result for two tapping management groups at the Jijike site, there was no significant difference in damage occurrence between annually tapped trees and those rested for 2.5 years (Z = -0.084; P = 0.933). Damage occurrence rates were 84 ± 3.6% (mean% ± S.E.) for annually tapped and 84 ± 3.8% (mean % ± S.E.) for trees rested for 2.5 years.

The damage percentage on branches and stems on annually tapped trees versus those rested for 2.5 years was not significantly different (Z = -0.248; P = 0.804) (Figure 6a). Total stem damage observed in Jijike was 3.6% (the sample comprised 4 trees that had been annually tapped and 3 trees that had been rested for 2.5 years).

Similar to in Kafta Humer, there was less beetle damage percentage on branches of smaller diameter trees ($\chi2 = 60.062$; $P < 0.001$) than on medium or larger diameter class (Figure 6b). There was no significant difference in branch damage percentage between different tree diameter classes >15 ≤ 25 cm; and > 25 cm (P = 0.0567). Generally there was a significant and positive correlation between tree diameter size and branch damage percent on *B. Papyrifera* trees in Jijike site ($r_s = 0.544$; $P < 0.001$).

3.2. Effects of tapping intensity (stem wounding) on longhorn beetle damage prevalence

In Kafta Humera, tapping intensity had an impact on longhorn beetle damage occurrence ($\chi2 = 17.719$; $P = 0.001$). Less longhorn beetle damage occurrence was observed on untapped trees (46 ± 7.5%) than on tapped trees with 6 points (72 ± 6.4%) (P = 0.005), 7–12 points (78 ± 5.9%) (P = 0.001), or more than 12 points (80 ± 5.7%) (P = < 0.001). There was no significant difference between untapped trees and those with less than 6 points tapped trees (62 ± 6.9%) (P = < 0.080).

The degree of damage (percent of crown branches damaged) on crowns of *B. Papyrifera* trees with wounding at more than 12 points was very high compared to other tapping intensities ($\chi2 = 37.395$; P = < 0.005) (Figure 7a). Less crown damage percentage was observed for unwounded trees than wounded ones at various intensities (Figure 7a).

In Jijike site situation, there was no significant difference for beetle damage occurrence among different tapping intensities ($\chi2 = 5.597$; $P = 0.133$). Percentage of damage occurrence for trees wounded with less than 6 points, 6 points and 7–12 points and greater than 12 points were 74 ± 6.3%, 82 ± 5.5%, 88 ± 4.6% and 90 ± 4.3%, respectively.

Tapping intensity had an impact on the degree of damage on *B. papyrifera* tree branches ($\chi2 = 13.442$; $P = 0.004$). Tree wounding with more than 12 points showed high percentage of branch damage compared with other tapping intensities ($P < 0.005$ in all group-paired cases). There was no difference in branch damage percentage among tapping intensity levels, less than 6 points, 6 points and 7–12 points ($P > 0.05$ in all group-paired cases) (Figure 7b).

4. Discussion

4.1. Longhorn beetle damage for different resting periods and wounding intensity of B. papyrifera trees

In northern Ethiopia, different management interventions can increase frankincense yield, reduce the impact of over harvesting and thus may reduce biodiversity loss (Tilahun et al., 2011; Negussie et al., 2018). One of the dry forest restoration interventions in northern Ethiopia is improved tapping management, leaving *B. papyrifera* trees untapped for some years. This study clearly demonstrated that the frankincense tree is under risk because of longhorn beetle damage, which has been exacerbated by poor tapping management. In both study areas, we found that trees tapped with less than ten years tapping interval were vulnerable to longhorn beetle damage. The damage was more pronounced on larger diameter trees than smaller diameter trees which were associated with high tapping intensity of larger trees and high branch numbers that host many longhorn beetles. Farmers observed that high tapping intensity or wounding of smaller trees (< 15 cm diameter) may increase tree mortality. Similarly, Eshete et al. (2012) reported that trees subjected to frequent and heavy tapping were vulnerable to insect attack. Asfaw et al. (2019) also found that trees tapped every year without rest have low frankincense yield and high mortality probability. Such damage might also reduce flower and fruit production and reduce seed viability (Rijkers et al., 2006), which could affect future frankincense production as well as natural regeneration of the species in its natural habitat (Bongers et al., 2019).

As reported by Negussie et al. (2008), Abiyu et al. (2010), Groenendijk et al. (2012) and Bongers et al. (2019), *B. papyrifera* natural regeneration is disturbed by unsustainable tapping, fire, livestock pressure, insects, drought, and habitat fragmentation for agricultural uses. Though it needs further study, *B. papyrifera* trees require longer resting periods (at least 3 years) to recover from previous wounds and withstand insect and disease damage. Exudation after wounding or damage is assumed to protect plants from insect damage by sealing off injured tissue, preventing desiccation, and protecting the trees from secondary attack by insects and fungi and preventing further injury through decay (Phillips and Croteau, 1999). Once a beetle bores through the outer bark into the inner tissues, resin starts to flow, blocking the entrance hole made by the insect, expelling it from the tree (Phillips and Croteau, 1999; David and Crutchfield, 2006; Eshete et al., 2012; Tolera et al., 2013). Trees that are sufficiently hydrated often manage to expel the invader through sufficient flow of resin.

Intensive tapping prevents resin accumulation by reducing the photosynthetic capacity of *B. papyrifera* through a decrease in total leaf

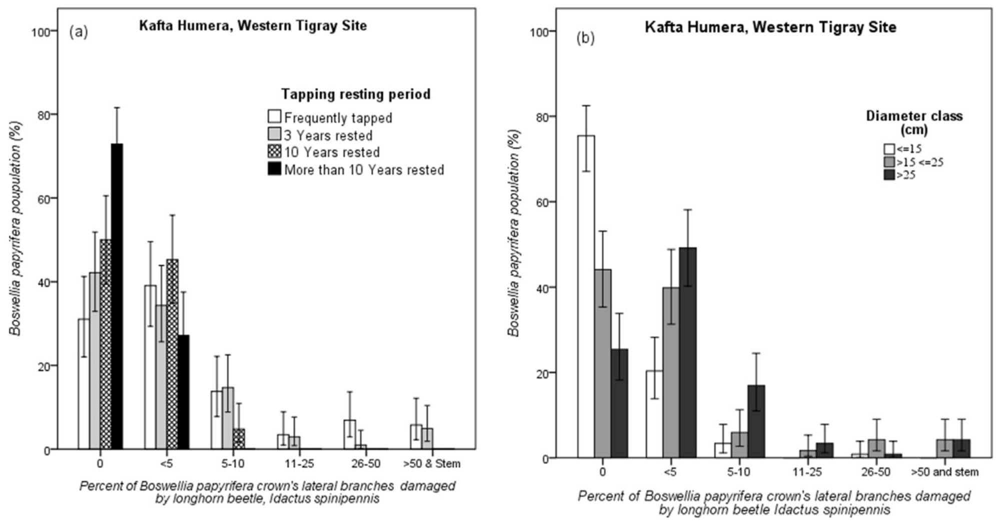

Figure 5. Frequency percentage of *Boswellia papyrifera* trees and level of damage by long horn beetle, *Idactus spinipennis* (a) for different tapping resting periods and (b) tree diameter sizes at Kafta Humera, Western Tigray site.

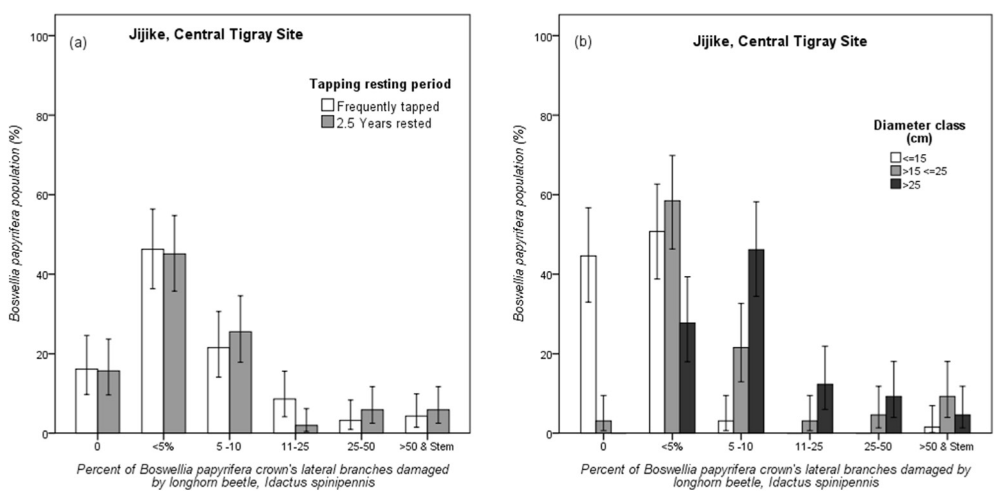

Figure 6. Frequency percentage of *Boswellia papyrifera* trees and level of damage by long horn beetle, *Idactus spinipennis* (a) for different tapping resting periods and (b) tree diameter sizes at Jijike, Central Tigray site.

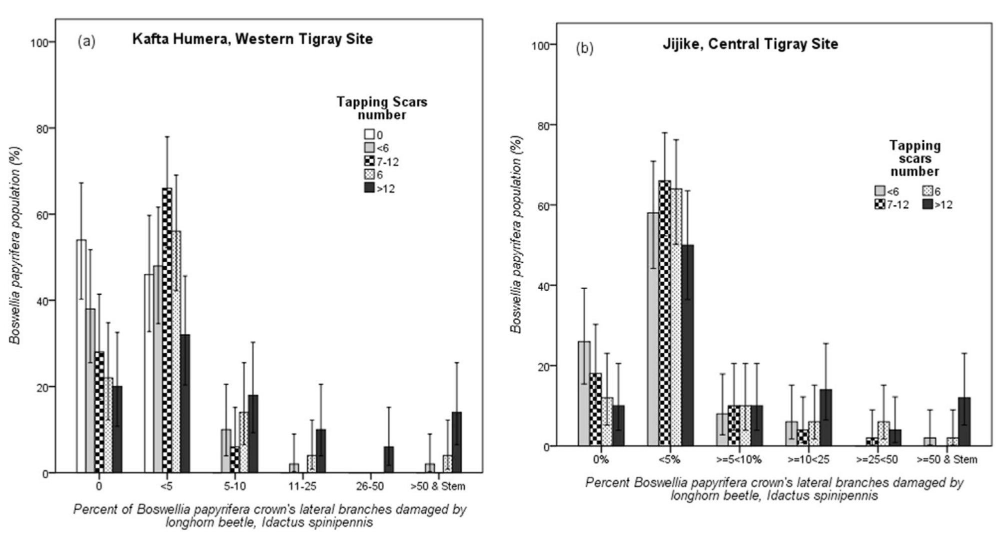

Figure 7. Frequency percentage of *Boswellia papyrifera* trees and level of damage by longhorn beetles with different wondings for frankincense collection (a) at Kafta Humera, WestPhoern Tigray site and (b) at Jijike, Central Tigray site.

area and thus a reduction in carbon gain (Mengistu et al., 2012). This will also reduce the amount of resin available for defense against insect wounds and further damage to the whole tree. The traditional system of tapping *B. papyrifera* trees involves making wounds on the living bark of the tree. At the beginning, small incisions are made and these expand in the subsequent wounding periods (between 12 and 14 rounds) in the same year. Eshete et al. (2012) recommended wounding spots should be restricted to 9 points per tree in one tapping season. Due to poor management, illegal practices, and short time horizons, farmers often make multiple wounds, usually more than nine, thus intending to harvest more frankincense without considering tree health and subsequent damage.

In the present study, untapped trees and trees tapped with less than six wounds showed less longhorn beetle damage percentage on their branches than those heavily wounded trees with 12 and more points.

A similar study in Eritrea on the same species also reported that tapping at six points is normal while tapping at 12 points or more is affects the health of the tree (Ogbazghi et al., 2006; Rijkers et al., 2006). Eshete et al. (2012) reported the amount of tapping wounds and the number of tapping rounds for frankincense harvest reduces total frankincense yield; they suggested three tapping wounds for trees with a diameter size between 10-15 cm in diameter, six wounds for trees 15–20 cm in diameter and nine wounds for trees > 20 cm in diameter. More wounds made when the frequency of tapping is increased can deplete the stored carbohydrates reserves, weakening the tree and reducing defenses against insect damage. Moreover, tapping for frankincense collection is practised during the dry season, when *B. papyrifera* trees shed their leaves and depend entirely on stored carbohydrates (Mengistu et al., 2013).

Insects are mainly attracted to trees with less vigor and lured to visible wounds for food and good oviposition sites to continue their life cycle (Negussie et al., 2018). When trees are weak and wounded, phytophagous insects and their associated microorganisms can quickly gain the advantage against host trees (Phillips and Croteau 1999; Morewood et al., 2004). Therefore, depending on their diameter size, *B. papyrifera* trees should be wounded less than 12 points per tree to minimise insect damage and subsequent physiological stress.

5. Conclusion and management recommendation

Both increasing demand for frankincense products and its high commercial value in East Africa has resulted in over-harvesting, that maximizes short-term economic gains with little or no consideration for long-term socio-ecological consequences. Improper traditional tapping practices to harvest frankincense from *B. papyrifera* trees have a detrimental effect on tree health and increase the prevalence of longhorn beetle damage. Frequent and excessive extraction of frankincense without resting periods of at least 3 years makes trees more vulnerable to insect damage. This has led to low yields and may cause poor frankincense quality, a decline in the tree population and poor natural regeneration, which might lead to local extinction of the species. More wounding may increase the yield of frankincense temporarily, but reduces the long-term productivity and susceptibility to insect damage and mortality. Continuous resin tapping without rest and excessive tapping more than 12 points wounding per tree increases longhorn beetle damage prevalence. Though additional studies are recommended, Boswellia remnant forests or woodlands need three and more years of resting period after one year tapping to reduce *B. papyrifera* trees susceptibility to insect damage. Depending on tree diameter size, wounding points should be less than 12 points over a single tapping season from the same year.

Declarations

Author contribution statement

Aklilu Negussie: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kindeya Gebrehiwot; Mekonnen Yohannes: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Lindsey Norgrove: Analyzed and interpreted the data; Wrote the paper.

Ermias Aynekulu: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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