Journal of Arid Environments 152 (2018) 6–11

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

An exploratory survey of long horn beetle damage on the dryland flagship tree species *Boswellia papyrifera* (Del.) Hochst

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

[a] WeForest, Ogentroostlaan 15, B-3090 Overijse, Belgium
[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] World Agroforestry Centre (ICRAF), United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya
[e] Ethiopian Environment and Forest Research Institute, Mekelle Centre, Tigray, Ethiopia
[f] School of Agricultural, Forest and Food Sciences, Bern University of Applied Sciences, Zollikofen, Switzerland
[g] Department of Environmental Sciences (Biogeography), University of Basel, St Johanns Vorstadt 10, CH-4056 Basel, Switzerland

A R T I C L E I N F O

Keywords:
Frankincense tree
Dryland
Insect
Idactus spinipennis
Exclosure
Open grazing
Ethiopia

A B S T R A C T

Boswellia papyrifera (Del.) Hochst, a flagship tree species in the drylands of Ethiopia, is of high ecological, economic and social value. Recent work has shown that a wood-boring beetle is threatening its survival. *In situ* and *ex situ* studies were carried out to study the biology and damage associated with the insect in the dry lowlands of Northern Ethiopia. The beetle's life cycle, biology, and population were studied for 10 months. The mortality of *B. papyrifera* trees due to the wood-boring beetle was assessed in two land management systems (managed and unmanaged) in 64 (400 m^2) randomly allocated plots in Boswellia woodlands of Central and Western Tigray. The beetle was identified as *Idactus spinipennis* Gahan. Average annual tree mortality attributed to *I. spinipennis* was up to 7% and 8% ha^{-1} for Central and Western Tigray, respectively. *I. spinipennis* has a detrimental effect on the succession of Boswellia woodlands, causing resource loss and fragmentation. Estimated average losses in Central Tigray were 45.7 kg frankincense ha^{-1} (US $137.1 ha^{-1}) and 26.9 kg frankincense ha^{-1} (US $80.6 ha^{-1}) from unmanaged and managed *Boswellia* woodlands, respectively. Hence immediate management interventions are required to reduce ecological and economic loss of the *Boswellia* woodland.

1. Introduction

Long Horn Cerambycidae beetles (wood boring insects) are widely recognized agents of ecosystem disturbance that can have an impact on tree growth and nutrient cycling, and outbreaks can create large-scale disturbances in forest succession (Schowalter, 1981, 2000; Filion et al., 1998; Eshleman et al., 2000; Eisa and Adam, 2010). Insect outbreaks cause tree species loss and widespread vegetation damage in many countries (BIS, 2011; Moore and Allard, 2011). For example, the long horn beetle has damaged *Acacia senegal* and *A. seyal* in Sudan (Eisa and Roth, 2008; Eisa and Adam, 2010).

In the dry lowlands of Ethiopia, a Cerambycidae insect is threatening *Boswellia papyrifera* (Del.) Hochst, the white frankincense-producing tree. *Boswellia papyrifera* is deciduous, reaching 16 m height or more with a rounded crown (Azene et al., 1993; Fitchl and Admasu, 1994; Gebrehiwot, 2003; Gebrehiwot et al., 2003; Yirgu et al., 2014). The product, frankincense, the white oleo-gum-resin exudate, has a long history of human use. The oil content and pleasant smell of frankincense has made it favorable to burn as incense in temple rituals and as a base for perfumes and for medicinal purpose (Gebrehiwot et al., 2003; Lemenih et al., 2003; Woldeselassie et al., 2006; Groenendijk et al., 2012). Ethiopia is one of the world's major frankincense suppliers: in 2007/2008, 3834 Mg of gums and resins were exported, valued at US$5.2 million (Lemenih and Kassa, 2011a). From 1997–2008, Ethiopia exported 29,340 tonnes of natural gums and resins (90% of which was frankincense), and earned US $38 million (Lemenih and Kassa, 2011b). Such revenue is a buffer against economic risks and an alternative income source for the dryland poor through both frankincense collection and trade related activities (Tilahun, 1997; Lemenih and Teketay, 2003; Lemenih et al., 2007).

However, frankincense production is declining due to insect outbreaks, land-use changes and over-intensive resin tapping combined

* Corresponding author.
E-mail addresses: aklilumekuria@weforest.org (A. Negussie), kindeya.gebrehiwot@mu.edu.et (K. Gebrehiwot), mekonnen.yohannes@mu.edu.et (M. Yohannes), e.betemariam@cgiar.org (E. Aynekulu), bmanjur@korea.ac.kr (B. Manjur), lindsey.norgrove@bfh.ch (L. Norgrove).

https://doi.org/10.1016/j.jaridenv.2018.01.011
Received 23 June 2016; Received in revised form 17 January 2018; Accepted 19 January 2018
Available online 01 February 2018
0140-1963/

with poor tree management. The tree is listed by IUCN as amongst those endangered species that need priority attention (Marshall, 1998). Long horn beetle damage is one of the main factors contributing to these losses. This paper presents data from a scoping study and is the first description of the biology of and quantification of the damage caused by the long horn beetle from Ethiopia. The main aims of this study were to (i) understand the beetle life-cycle and population status in infested trees through *in situ* and *ex situ* observations and experiments; (ii) estimate damage and (iii) estimate economic loss as a result of long horn beetle damage in degraded Boswellia woodlands of Central and Western Tigray, Northern Ethiopia.

2. Materials and methods

2.1. Study site

The study was in Tanqua Abergele district in Jijike area (Central Tigray) and Kafta humera district, Tekeze area (western Tigray) where *Boswellia papyrifera* is abundant (Fig. s1).

The first site, Jijike (Central Tigray), is approximately 160 km east of the regional capital, Mekelle, in the lower Geba river catchment, northern Ethiopia. Altitude varies from 1400 to 1650 m a.s.l. Along the drainage lines of the landscape, soil types are Chromic Cambisols and Arenosols formed over an intimate mixture of Mesozoic limestone and pre-Cambrian schist with local veins of quartzite. Elsewhere, Leptosols are dominant. Soils are shallow, with a high degree of stoniness which significantly limits both the water holding capacity and the potential root space (Goris, 2002). Mean annual rainfall is 657 mm, most of which occurs between mid-June and August, with a long dry season of 9 months (Negussie et al., 2008). Mean annual temperature is 22.3 °C with minimum and maximum temperatures of 20 °C and 31.3 °C (Kinsman and Platt, 1984; Negussie et al., 2008). The natural vegetation is dry woodland, dominated by *B. papyrifera*, *Acacia etbaica* Schweinf. *Terminalia brownii* Fresen. and *Lannea fruticosa* Engl. Most of the woodlands in the area have been heavily fragmented by subsistence cultivation, fire, livestock grazing, soil erosion and over-harvesting for fuel wood, gum and resin, animal fodder and fiber (Negussie et al., 2008).

The second site, Tekeze, (Western Tigray) is located near the Tekeze River catchment, approximately 500 km from the regional capital, Mekelle. The altitude varies from 560 to 1849 m.a.s.l. The climate of the area is predominantly dry with a mean annual rainfall of approximately 581 mm, occurring between June and August. The mean annual temperature is 28.5 °C ranging from 20.2 °C mean annual minimum to 41.7 °C mean annual maximum temperature (Sertse, 2003; Negussie, 2008). Rock parent material of the area is dominated by volcanic felsic and metamorphic pre-Cambrian basements (ADCOH, 1996) and in some parts limestone is seen. Leptosols and Vertisol are the predominant prevailing soil types. *B. papyrifera* is the dominant tree species, followed by woody species such as *Dichrostachys cinerea*, *Anogeissus leiocarpus*, *Combretum hartmannianum*, *Acacia mellifera*, *Combretum fragrans* and *Lannae fruticosa* Engl.

2.2. In situ and ex situ observations and experimental set-up

In situ and *ex situ* studies were carried out to identify and study the biology of the long horn beetle, to estimate beetle populations in defined branch sizes and to estimate the degree of damage to the fragmented dry woodlands in Northern Ethiopia, Tigray.

In Central Tigray, *in situ* population counts were made in the field to determine populations of adult beetles emerging from already infested and dead *B. papyrifera* tree branches. Sixty infested branches with an average branch diameter of 0.07 m (length ranges between 0.2 m and 1.5 m), were collected randomly from 60 *B. papyrifera* trees both from open grazed (unmanaged) and closed protected (managed) lands to count adult beetle exit holes. When adult beetles emerge through the surface of the wood, they leave exit holes, which provide information about the type of beetle and current activity (Feller and Mathis, 1997; Feller, 2002). As counting adult beetles in the field is very difficult, populations are typically censused by counts of defined exit holes in dead branches of defined size category (Collinge et al., 2001), so we used this method to estimate population density.

Ex situ controlled experiment were also established in the greenhouse at Mekelle University, Northern Ethiopia (13° 28′N and 39°29′ E at an altitude of 2200 m a.s.l.) to assess the biology of the long horn beetle. Mean annual minimum and maximum temperatures of the area are 13 and 23 °C, respectively. Three (2 m × 2 m × 2 m) mesh wire cages were prepared and 3 big infected *B. Papyrifera* branches (average size 0.08 m diameter, 1.8 m height) were placed inside and kept upright by planting in big pots. They were observed for 10 months. At the end of the experiment the branches were dissected and the remaining larva were checked inside the branch part.

Four additional 0.5 m × 0.5 m × 0.5 m white cotton cloth-covered cages were prepared to observe the final developmental stages of the beetle, to count the actual number of adult beetles, and to collect adult specimens, whose length and width were measured. In each cage, 1 branch with a diameter of 0.06 m and 0.5 m length was placed and monitored for 5 months (observations were made once a week). To identify the insect, the insect specimen collections in Addis Ababa University were checked and different insect books were reviewed (e.g., Breuning, 1938a,b; Breuning and Villiers, 1972; Milius, 1999; Booth et al., 1994; Ozdikmen, 2006). Some adult Cerambycidae samples were caught, pinned and sent to Belgium (KU Leuven) for further identification.

2.3. Tree mortality caused by longhorn beetle and extent of damage

The extent of long horn beetle damage on *B. papyrifera* dominated woodland was assessed from September 2005 to August 2009 in 32 (20 m × 20 m) randomly allocated plots: 16 open grazed (unmanaged) and 16 exclosure or managed (protected from livestock and humans) in Central Tigray. The selected exclosure (managed) had been protected from livestock interference since 1994; but frankincense tapping had been allowed.

In addition, 32 (20 m × 20 m) randomly allocated plots: 16 open grazed (unmanaged) and 16 exclosure or managed (protected from livestock and humans) plots were also assessed in Western Tigray, Kafta Humera, Tekeze area, to establish the occurrence and extent of damage in the other *B. papyrifera* growing area in Tigray. In Tigray Region, *B. papyrifera* and other gum and resin bearing trees are found dominantly in Central and Western Tigray.

In both sites, the extent of damage was quantified for every *B. papyrifera* tree in the plots (both managed and open grazed). The total number of branches and the number of beetle damaged branches were counted, the latter categorised by the presence of frass and holes. The proportion of infested branches in the crown was calculated.

2.4. Assessment of economic loss

Assuming: a single *B. papyrifera* tree produced 471.5 g of raw gum annually (Tilahun et al., 2011); the selling price is US $3 kg $^{-1}$ (Sisay and Samual, 2011); Tigray's current total *B. papyrifera* cover is 330,000 ha (Tilahun et al., 2007); and, the average tree stand density is 394 trees ha $^{-1}$ (Negussie, 2008).

2.5. Statistical analysis

We first conducted tests for normality (Kolmogorov–Smirnov *D* statistic) and equality of variance (Levene statistic) on all collected data. Differences in tree mortality as a result of beetle damage between grazed woodlands and exclosures were analyzed using one way ANOVA. A Pearson correlation test was used to assess the relationship