International Journal of Tropical Insect Science
https://doi.org/10.1007/s42690-022-00856-w

ORIGINAL RESEARCH ARTICLE

First record of *Neoplocaederus conradti* (Kolbe) (Insecta, Coleoptera, Cerambycidae) as a pest of *Boswellia papyrifera* (Del.) Hochst in Ethiopia

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Received: 27 April 2022 / Accepted: 21 July 2022
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Abstract
The Frankincense tree *Boswellia papyrifera* (Del.) Hochst is native to Ethiopia and is the chief source of frankincense, the aromatic resin used in incenses and perfumes. However, the production of frankincense decreases from time to time due to many factors, including insect attacks, but no information was available about the identity and importance of a large wood-borer found damaging this tree. Field research done in the area of Humera, Ethiopia, in October 2019 lead to the discovery of *Neoplocaederus conradti* (Kolbe, 1893) (Coleoptera, Cerambycidae, Cerambycinae, Cerambycini) as a serious pest of *Boswellia papyrifera*. This tree is the second known host for this borer. Field observations strongly suggest that proper tapping of trees is a crucial method to prevent attacks by this beetle.

Keywords Frankincense tree · Longhorn beetle · Stem borer · Tapping · Humera

Introduction

Six *Boswellia* species – *B. papyrifera* (Del.) Hochst, *B. neglecta* Moore, *B. microphylla* Chiov., *B. ogadensis* Vollesen, *B. rivae* Engl. and *B. pirrotae* Chiov. – occur in Ethiopia and all species are currently tapped for incense (Lulekal et al. 2012; Thulin 2020). Frankincense is mainly extracted from *B. papyrifera* in Ethiopia, which is the leading producer of frankincense (Lemenih and Teketay 2003). It is exported to the United Arab Emirates, Poland, Middle East, and Asian countries, particularly Japan and China (Lemenih and Teketay 2004).

Boswellia papyrifera is a tree to 10 (-12) m that is widely distributed in the northern part of the *Combretum-Terminalia* woodland and wooded grassland west of the Ethiopian Highlands with a less significant geographical extension to the Rift Valley (Friis et al. 2022). It is often dominant on steep rocky slopes, lava flows or sandy valleys, and in areas where annual rainfall ranges from 100 to 800 mm with an annual temperature from 25 to 40 °C (Eshete et al. 2005). Outside of Ethiopia, *B. papyrifera* occurs from Nigeria to Eritrea and south to Uganda at altitudes down to 250 m a.s.l. (Friis et al. 2022). Inside Ethiopia, it is recorded from an altitudinal range between 750 and 1800 m.a.s.l. (Friis et al. 2022). This tree provides several economical, ecological and cultural benefits in the Ethiopian drylands since collection, tapping, grading, processing and marketing activities in frankincense production create a variety of job opportunities.

However, the populations of *B. papyrifera* are declining due to extensive farming, over-grazing, and intensive and improper tapping practices all of which increase the chances of forest fires and attacks by organisms such as fungi (Gezahgne et al. 2014), termites and other insect pests (Ogbazghi 2001; Rijkers et al. 2006). Insect pests have considerable impacts on *B. papyrifera.*, and a large longhorn beetle has recently been found to threaten *B. papyrifera* in the dry lowlands of Ethiopia. Other indigenous trees have become endangered, and many severely affected trees in the area looked completely dead and dry without having fallen (Fig. 1). Aklilu (2008) recorded *Idactus spinipennis* Gahan,

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Published online: 08 August 2022

Fig. 1 Exit holes of *Neoplocaederus conradti* on *Boswellia papyrifera*

Fig. 2 *Neoplocaederus conradti* adult

1890 (Coleoptera, Cerambycidae, Lamiinae) as boring in trunks of *B. papyrifera* Currently, *I. spinipennis* is the only cerambycid reported to be a pest of this tree (Negussie et al. 2021) but it seemed too small to account for the observed damage. The present study aimed to identify another pest of *B. papyrifera* in Ethiopia, which has a bigger impact on this tree.

Materials and methods

The investigation area is located in Ethiopia, in the Northwestern parts of the Amhara Regional State, Humera district, between 13.042° to 14.028° latitude and 36.020° to 37.031° longitude, 420 km away from the capital of the region, Bahir Dar, and 984 km northwest of Addis Ababa. The altitude of the district ranges between 560 and 940 m above sea level. The climate of the area is largely characterized by the upper kola agro-ecological zone, with a mean annual rainfall of 581.2 mm and a temperature range between 20 and 41°C (Humera Agricultural Research Center 2019). The site is one the most extensive areas of natural *B. papyrifera* stands and it is known for the large quantity of incense production.

During October 2019, the first two authors conducted a field survey and examined both tapped and untapped *B. papyrifera* trees for borer symptoms along with completely dried trees. The presence of holes on the surface of stems was used to identify insect attacks (Fig. 1). Adults were easily identified using Adlbauer and Beck (2015).

Results

Larvae, pupae and adults of *Neoplocaederus conradti* (Figs. 2 and 3) were collected from stems measuring 18–32 cm in diameter, by cutting and dissecting the heartwood and carefully using a saw to collect samples from purposely selected trees (Fig. 4).

Insect borer symptoms (entrance and exit holes) were clearly and commonly observed on improperly tapped *B. papyrifera* trees during the field survey (Fig. 5), although we did not collect quantitative data on the prevalence of entrance and exit holes on these improperly tapped trees. In contrast, we did not observe borer symptoms on untapped and properly tapped *B. papyrifera* trees. This is in line with the observation that improper tapping exposes trees to attacking insects, fungi, bacteria and viruses (Rijkers et al. 2006; Trapp and Croteau 2001; Aklilu 2008; Abrham et al. 2010).

Recently, Sommerlatte and Wyk (2022) recorded this cerambycid as a pest of *Commiphora confusa* Vollesen, a frankincense producer in Kenya. Thus, *B. papyrifera* is the second known host for this longhorn beetle.

Fig. 3 *Neoplocaederus conradti* pupa

Fig. 4 Larval galleries of *Neoplocaederus conradti* in *Boswellia papyrifera*

Discussion

The deciding factors for infestations by cerambycids are nutrient content, moisture and temperature (Svacha and Lawrence 2014). Weakened trees are more susceptible to borer attacks; thus, the best way to avoid borers is to keep trees in good health (Frank and Baker 2018). Moreover, insect borer symptoms, including canker formation, exudation of gum, wilting, dieback, vascular browning and death of trees were observed especially on improperly tapped *B. papyrifera* trees (Gezahgne et al. 2014).

Traditionally, *B. papyrifera* produces frankincense through artificial wounding of the trees, a process called

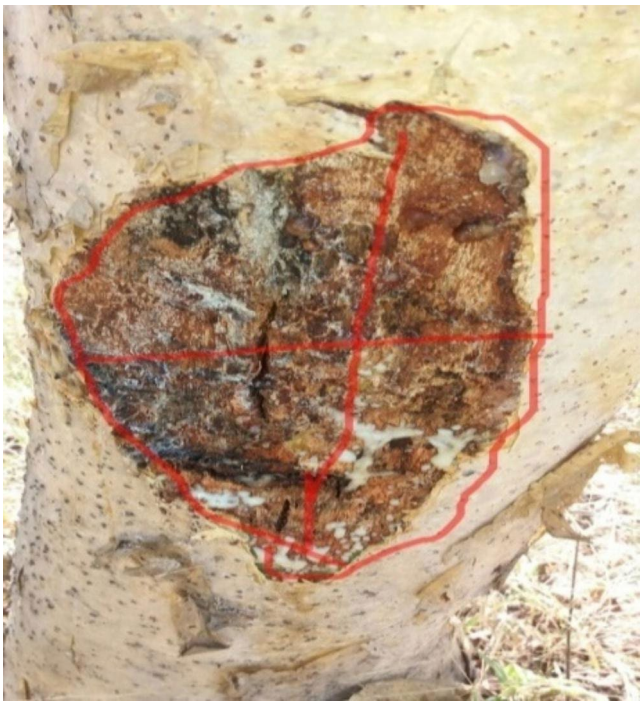

Fig. 5 Trunk of *Boswellia papyrifera* with large and improper tapping scar

tapping. Proper tapping involves slight shaving the external layer of the bark and the formation of a circular wound of about 1–2 cm high, 1–1.5 cm wide, and 0.5–1.0 cm deep. Usually 3 tapping spots are made on each side of the tree (east and west), starting at about 0.5 m from the base of the stem (Lemenih and Kassa 2011). Proper tapping of trees towards sunlight (east and west) directions increases the yield of frankincense (Ammar et al. 2015).

Improper tapping of trees (Fig. 5) with too much exposure of the inner bark will result in damage to adult trees by exposing them to fire, larvae and other attacks (Eshete 2002). The current practice of tapping is too intensive and damaging and it is negatively affecting survival, growth and reproduction of trees (Ogbazghi 2001; Rijkers et al. 2006; Eshete 2010). Tapping of the tree according to proper directions showed significant results (Ammar et al. 2015); however, in the study area, trees were tapped in all directions.

Finally, a larva of a click beetle (Coleoptera, Elateridae) (Fig. 6) was observed in a trunk colonized by larvae of *N. conradti*. Since elaterid larvae can be predaceous on xylophagous insects, the future identification of this species might lead to employing it in biological control. Unfortunately, keys to larvae of African species are still unknown and adults of the elaterid have not yet been found.

Fig. 6 Larva of unknown species of click beetle found in *Boswellia papyrifera*

Conclusions

The Frankincense tree *B. papyrifera* is an economically important plant, particularly in Ethiopia. However, its population has been declining and trees are often degraded in its natural habitat. It needs more attention concerning conservation, propagation, rehabilitation and adequate sustainable management. The present new record of *Neoplocaederus conradti* as a serious pest of *B. papyrifera* is an important contribution to the conservation of this tree. In addition, the observation that untapped or properly tapped trees did not show borer symptoms suggests a crucial method to prevent the attacks. We recommend proper tapping size and direction, season, and provision of a sufficient resting period as absolutely essential for recovery of the species. It is also important to look for other alternative incense production options and consider protecting wounds from direct exposure to insect and fungal infection. Finally, an asyet unidentified click beetle species might be used in the future for biological control.

Acknowledgements We acknowledge the Ethiopian Forest Research Centre for its financial support during field works. The authors appreciate the contribution of Dr. Abeje Eshete and Mr. Abraham Yirgu, Ethiopian Forest Research Centre, for providing information about insect pest symptoms on *B. papyrifera* trees in the study area, which were afterwards identified as attacks of *Neoplocaederus conradti*. We thank Ms. Odile Weber, National Museum of Natural History, Luxembourg, for drawing our attention to a recent publication documenting the phytogeographical distribution of *B. papyrifera* in Ethiopia. Finally, we are grateful to Mr. Daniel Heffern, Houston (USA) for his valuable linguistic revision of the text.

Declarations

There were no external sources of funding for this article as it was undertaken as independent research. The authors declare that they have no conflict of interest.

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