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Assessment of wounding factors (natural and anthropogenic) of *Juniperus procera* and their relation to disease occurrence of *Pyrofomes demidofffii* in some afromontane forests of Ethiopia

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ABSTRACT

Wood decay fungus *Pyrofomes demidoffii* is a cosmopolitan spp. and considered as an important source of damage to *Juniperus* spp. The aim of the study was to assess the wounding factors of *Juniperus procera* and their relation to a disease occurrence of *P. demidoffii* in some afromontane forests of Ethiopia. Disease survey and sample collection was conducted during 2010 in Adaba-Dodola and in Menagesha forests. In Adaba-Dodola forest, sampling was conducted in highly disturbed forest blocks named as non-"WAJIB" and in a relatively undisturbed forest ("WAJIB") named after the local Afan Oromic language. WAJIB blocks are constitute of Forest Dwellers Association established to protect forest, whereas a non-WAJIB blocks are people living in villages found adjacent to forests with little role in protection of forest. In both study areas, a study quadrat of 20 × 20 m^2 within the plot was established at 100 m intervals along a regular grid. In each sampling unit, comprehensive survey was conducted to determine the occurrence of infection by *P. demidoffii*. About 657 trees (310 in Adaba-Dodola forest and 347 in Menagesha forest) were assessed for the typical signs and symptoms of *P. demidoffii*. Natural and anthropogenic wounding factors were assessed, and their relationships with disease occurrence of *P. demidoffii* were determined. *Pyrofomes demidoffii* was noticed as fruiting bodies and/or white rot on the juniper stands. The disease occurrence of *P. demidoffii* was significantly higher in juniper stands with a mixed wounding factors followed by wounding by bark-peeling ($P < .0001$). The disease occurrence was significantly associated with crown vitality status ($P < .0001$) and significantly higher in juniper stands with complete-die back. The disease occurrence in the intact juniper stands was much lower both from fruiting bodies (9.1%) and white rot (3.6%) as compared to other decay stages. Trees with larger diameter at breast height (d.b.h) and larger wound size displayed significantly higher disease occurrence of *P. demidoffii* ($P < .0001$). Wounding at any point has resulted in the infection of the tree by fungal inoculum of *P. demidoffii*. From the current study, it can be concluded that wounding of the juniper tree by mixed wounding factors followed by bark peeling; wounds of larger size; heavily decayed and hollowed trees; completely declined stands, and stands with larger d.b.h. categories enhanced the susceptibility of juniper tree to *P. demidoffii* to a greater extent.

1. Introduction

Juniperus procera Hoechst ex Endl., commercially known as the African pencil cedar, locally known as 'Tedh' in Amharic language, belongs to the family Cupressaceae and the largest juniper in the world (Negash, 1995, 2010). It occurs wild from Sudan, Eritrea and Ethiopia southwards through East Africa and eastern DR Congo to Malawi and Zimbabwe; it also occurs wild in Saudi Arabia and Yemen (Lind and Morrison, 1974; Friis, 1992; Negash, 1995, 2010; Couralet and Bakamwesiga, 2007). It is a characteristic tree of the undifferentiated and dry Afromontane forest types (Friis, 1992; Bekele, 1993; Couralet and Bakamwesiga, 2007). It is hardy and tolerant to drier climatic conditions (Negash, 1995, 2010).

Juniperus procera produces timber of high economic importance with very strong, durable and immune from the attacks of fungi, termites or other borers due to high oleo-resins content (Pohjonen and Pukkala, 1992). Its wood is widely used for manufacturing of lead-pencil and pen-holder, construction and lining of buildings, joinery, flooring, furniture and all sorts of outdoor work such as roofing shingles, fence posts, water flumes and transmission poles owing to its fine texture, straight grain, medium hardness, resistance to termite attack and workability (Dale and Greenway, 1961; Lind and Morrison, 1974;

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Table 1
Geographical location of study areas, climate data and specimen collection sites of *P. demidoffii* from *J. procera* in Ethiopian Forests.

Study Forest and study sites	Latitude (N†)	Longitude (E†)	MAT* (°C)	MAR† (mm)	Rainy season		Altitude Range (m.a.s.l.)
					Major	Minor	
Adaba-Dodola†	6°50′-7°00′	39°07′-39°22′	7–24	1200	July -Sept.	Mar.-Apr.	2,400–3100
Shushi-Shifa (W)	6°52′43.65″	39°11′45.50″					
Artu-Fite (W)	6°52′53.22″	39°12′58.29′					
Changiti (W)	6°53′07′.85″	39°1′13.03″					
Edo-Wite (W)	6°53′27.88″	39°8′43.10″					
Berisa (W)	6^{0}56′56.59″	39^{0}3′03.27″					
Botole (NW)	6°55′14.89″	39°11′15.36″					
Choloke (NW)	6°56′4.72″	39°11′44.58″					
Deneba (NW)	6°57′2.14″	39°11′27″					
Menagesha	8°57′53.84″-9°02′48.31″	38°32′27.62″-38°45′27.40″	12–16	1225	June-Sept.	Mar.-Apr.	2,400–3000

W WAJIB (Foresters Dwellers' Association); NW Non-WAJIB; refers to latitude or longitude (own's data); m.a.s.l. meter above sea level; * Maximum Annual Temperature; † Maximum Annual Rain fall. Source of Climatic data for study areas:-Adaba-Dodola forest (Couralet et al., 2005; Amente et al., 2006; Menagesha forest (Bekele, 1993; Senbeta and Teketay, 2001; Couralet et al., 2005).

Negash, 1995, 2010; Couralet and Bakamwesiga, 2007). The juniper's wood produces cedar oil that is used in microscopy, soap, perfumes, and medicines and abortions (Negash, 1995). Historically, it was recorded that *J. procera* forests in Ethiopia particular has been subjected to over 3000 years of anthropogenic influences (Teketay 1992; Darbyshire et al., 2003; Gebru et al., 2009; Sterck et al., 2010) and the existing, juniper populations are extremely small and fragmented in its natural habitat (Sterck et al., 2010).

Wood decay (or heart rot) fungi are considered as an important source of damage to both living trees and solid wood products (Sinclair et al., 1987; Manion, 1991; Johanneson and Stenlid, 1999). Heart rot fungi typically enter trees through wounds, damage by birds, mammals, and insects and lightning injury by using the discharge of airborne basidiospores. Besides, activities such as logging, pruning and/ or thinning, striking of trees with moving vehicles, and the misuse of axes and knives, conditions associated with weather contribute to heart rot fungi (Wagener and Davidson, 1954; Gilbertson, 1980; Scharpf and Goheen, 1993; Knapp and Soulé, 1999; Gregory et al., 2010; Garbelotto and Gonthier, 2013; Warren et al. 2013). Such factors contribute to the pathogenic effects of such fungi (Gregory et al., 2010; Garbelotto and Gonthier, 2013; Warren et al., 2013). They are capable of parasitizing and killing live young and mature trees (Hansen and Goheen 2000). It was also mentioned that infected trees display symptoms such as loss of crown, bark exudations (bleeding/resinosis and gummosis), dieback, wood discoloration, loss of consistency and vigour, as well as decay of almost all woody parts (Tchoumi et al., 2017).

Among wood decay fungi attacking *Juniperus* species, *Pyrofomes demidoffii* has been known as *Fomes juniperinus* (Schrenk) Sacc. & Syd., causing trunk rot on *Juniperus* spp. in North America (Hedgcock and Long, 1912; Lowe, 1952, 1955; Gilbertson, 1980; Gilbertson and Ryvarden, 1987; Scharpf, 1993; Scharpf and Goheen, 1993). It was also reported to cause of a white trunk heart rot on living *J. excelsa* in Europe (Ryvarden and Gilbertson, 1994), East Europe (Macedonia, Crimea, Caucasus) (Pilát (1936)), and Yugoslavia, Russia, and Pakistan (Ryvarden and Johansen, 1980) and Bulgaria (Ryvarden and Gilbertson, 1993; Alexov et al., 2012). It also causes white trunk rot on *J. excelsa* and *J. foetidissima* in Turkey (Doğan and Karadelev, 2006; Doğan et al., 2011), and on *J. formosana* in China (Dai and He, 2009). The fungus produce a thick-walled, elliposoid, subglobose to globose or truncate in shape and, variably dextrinoid, and cyanophilous (Ryvarden and Johansen 1980; Gilbertson and Ryvarden 1987; Ryvarden 1991; Ryvarden and Gilbertson 1994; Dai and He, 2009; Assefa et al., 2015), and enter its host through openings in the heartwood or in dead sapwood openings near the heartwood (Scharpf & Goheen, 1993), which may have a role in the initiation of juniper decay and disease.

Juniper tree is devastated by *P. demidoffii* and has been well noticed by farmers as destructive fungus mostly in old stands of *J. procera.* It is so called "somba kuta" or "onne kuta" in the local Oromic language, meaning an alien object harming the heart of the tree (personal communication with farmers Menagesha state forest). *Pyrofomes demidoffii* was generally regarded as the most harmful parasite in the old stands of *J. procera* in East Africa (Ethiopia, Kenya, Tanzania and Uganda) (Wakefield, 1915; Bryce, 1967; Ryvarden and Johansen, 1980; Nsolomo and Venn, 1994; Härkönen et al., 2003; Assefa et al., 2015). However, there is insufficient published information on the impacts of natural or man-made activities on the disease occurrence of *J. procera* by *P. demidoffii*. The aims of the present study were therefore to investigate the relationships between wounding factors and tree conditions (decay stages and crown vitality status) to disease occurrence of *P. demidoffii*; to assess the variation in disease occurrence among wound size categories or diameter at breast height (d.b.h.) of juniper stands; and to determine the variations in the occurrence of fruiting bodies among decay stages or wound size categories of *J. procera.*

2. Materials and methods

2.1. Study areas and field inventory

Field surveys were conducted in natural forest at Adaba-Dodola (southeastern Ethiopia), and Menagesha forest (central Ethiopia) for disease occurrence of *P. demidoffii* on *J. procera* during 2010. The geographical location and climatic conditions of the study areas are indicated in Table 1. The Adaba-Dodola forest is part of the Integrated Forest Management Project (IFMP) which is implemented through a new approach known as "WAJIB", meaning Forest Dwellers Association named after local Oromic language (Kubsa and Tadesse, 2002; Tadesse, 2006; Amente et al., 2006, 2010). With this approach, the anthropogenic impacts of human on natural forests have been reduced by involving the community living around the forest to share the benefits from the forest thereby conserving the forest (Kubsa and Tadesse, 2002; Tadesse, 2006; Amente et al., 2006,2010). Still, the Adaba-Dodola forest has been under considerable threat because of overexploitation of the forest for timber production and overgrazing (Couralet et al., 2005).

The Menagesha Natural Forest is a dry afromontane forest found in central Ethiopia, 50 km northwest of Addis Ababa at 9°00′N and 38°35′E (Friis, 1992; Bekele, 1993). The forest area is concentrated on the northwestern and southwestern half of the mountain, while the eastern slope has been converted into farmland (Senbeta and Teketay, 2001). Prior to human disturbance, the natural forest communities were: *Hypericum* belts, *Hagenia-Juniperus* forest, *Juniperus* forest, *Juniperus-Podocarpus* and *Podocarpus* forest. In forest of Menagesha, *J. procera* attains the highest sizes and is by far the most dominant, wounding more than 60% of the total basal area (Bekele, 1993). However, it has been also under commercial exploitation as early as the beginning of the