

An update on the occurrence of nematodes belonging to the genus *Bursaphelenchus* in the Mediterranean area

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The genus *Bursaphelenchus* contains more than 100 species of nematodes. Knowledge of the occurrence of nematodes belonging to this genus is a prerequisite for monitoring issues and control measures to prevent the introduction and establishment of pathogenic species such as *Bursaphelenchus xylophilus* into forest ecosystems. According to data collected from the published literature and databases such as Web of Science, FSTA, CAB Abstracts, Biological Abstracts and the EPPO Reporting Service, 22 *Bursaphelenchus* species have been recorded to be present in the Mediterranean region. These species are classified into nine morphological groups *sensu* Braasch, H., Burgermeister, W. and Gu, J. 2009 Revised intra-generic grouping of *Bursaphelenchus* Fuchs, 1937 (Nematoda: Aphelenchoididae). *J. Nematode Morphol. Syst.* 12, 65–88): *abietinus*, *eggersi*, *eremus*, *fungivorus*, *hoffmanni*, *kevinci*, *leoni*, *sexdentati* and *xylophilus*, although two species are currently not assigned to a specific group. Movement of insect vectors in international trade of wood and host plants into and within Mediterranean areas is considered the main pathway for *Bursaphelenchus* species dispersal. Many of the species represent a significant risk for pine and possibly other forest types, an annotated check-list of *Bursaphelenchus* species in the Mediterranean area, their main features, pathogenicity, host plants and insect vectors is presented.

Introduction

The genus *Bursaphelenchus* Fuchs (Nematoda, Parasitaphelenchidae) currently includes more than 100 species worldwide (Hunt, 2008; Kanzaki, 2008; Gu, 2014). Most of the species are associated with dead or dying conifer trees, mainly *Pinus* species (Braasch, 2004; Ryss *et al.*, 2005), although some of them might also associate with broad-leaved trees (e.g. *Quercus* spp., *Populus* sp. and *Alnus* sp.) or palms (e.g. *Cocos* spp.) (Cobb, 1919; Rühm, 1956; Tomalak and Filipiak, 2010; Carletti *et al.*, 2011; Vieira and Mota, 2013). *Bursaphelenchus* species are mainly mycophagous and under natural conditions are transmitted by different insect-vector species, either by maturation feeding or oviposition of the insect adults (Wingfield, 1987; Vieira *et al.*, 2004; Singh *et al.*, 2013). The insect vectors are mainly beetles, distributed in a wide range of different families, such as the Cerambycidae, Curculionidae (including subfamily Scolytinae) and Buprestidae (Rühm, 1956; Calvin, 1974; Braasch, 2001; Ambrogioni and Caroppo, 2002; Ryss *et al.*, 2005; Penas *et al.*, 2006).

In the genus *Bursaphelenchus*, only two species are known to act as plant-parasitic nematodes under natural conditions: *Bursaphelenchus cocophilus* Baujard 1989; Cobb, 1919) on *Cocos* species and *B. xylophilus* Nickle, 1970; Steiner and Bührer, 1934). The latter,

commonly known as the pinewood nematode (PWN), is one of the most damaging species in pine forests and is the causal agent of pine wilt disease (PWD) (Mota and Vieira, 2008). PWD involves a complex interaction between the nematode, its insect vector, host tree species and associated microbiota (fungi and bacteria) (Futai, 2013; Zhao *et al.*, 2014). The impact of the PWN on pine forest health, natural ecosystem stability and the international trade of wood and wooden products has generated extensive research on the distribution of *Bursaphelenchus* species and their related insect vectors worldwide. Despite this, information on host trees, vectors and potential damage of *Bursaphelenchus* species has remained limited.

Areas surrounding the Mediterranean are characterized by a climate of mild temperatures, with dry summers and a cold period during the winter. These weather conditions (average temperatures above 20°C during summer) are ideal for the development of *B. xylophilus*. Among the vectors, the most important and effective ones for spreading *B. xylophilus* are *Monoctonus* species (Evans *et al.*, 1996; Akbulut and Stamps, 2012). *Monoctonus galloprovincialis* Olivier, commonly known as the black pine sawyer beetle, is a wide spread species and it was identified as the vector of *B. xylophilus* in Portugal (Sousa *et al.*, 2001; 2002), and occurs also in other European countries. More detailed and