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EDITORIAL

Integrating science on *Xanthomonadaceae* for sustainable plant disease management in Europe

European Cooperation in Science and Technology (COST) is a funding organization for the creation of research networks, called COST Actions, that provide networking opportunities for researchers and innovators to strengthen Europe's capacity to address scientific, technological, and societal challenges. The EuroXanth COST Action CA16107, running from March 2017 to September 2021, created a pan-European network focusing on bacteria of the family *Xanthomonadaceae*, including species of *Xanthomonas* and *Xylella fastidiosa*. These bacteria belong to the most devastating plant pathogens continually challenging food security. Many of these pathogens, which infect all kinds of crop plants, such as cereals, forage crops for ruminant feed, vegetables, fruits, shrubs, and trees, are listed as quarantine or regulated organisms in the EU. Consequently, their study was considered of utmost importance for the European Community and beyond.

Over the last 4 years, the EuroXanth COST Action has held several workshops, working group meetings and international conferences, and organized training schools and international exchanges for technology transfer to early-career investigators and staff from less research-intensive countries in Europe (referred to as Inclusiveness Target Countries). As major deliverables, the COST Action has compiled resources about pathogen diagnostics, tools to study genetic diversity and population structures, repertoires of pathogenicity factors, sources of host resistance, and recommendations for disease control measures. Additionally, a database on type III effectors as key pathogenicity factors in *Xanthomonas* is being built and a Wiki-like platform has been generated for such effectors and for plant resistance genes against xanthomonad infection in a community science approach involving more than 70 scientists from 27 countries (http://www.xanthomonas.org/dokuwiki/).

Recent reviews have addressed several aspects of the infection cycle of xanthomonads, other aspects of the pathogens' biology, such as pigment synthesis, motility, and interaction with other microbes, and advances in biocontrol. Whereas these reviews focus on certain aspects of a group of pathogens, they do not describe a pathogen in its entirety. This gap is closed by the Pathogen Profiles, as published by the British Society for Plant Pathology in the journal *Molecular Plant Pathology*, which are unique in how they discuss a particular pathogen in detail, including its taxonomic status, life cycle, and host range. Descriptions of disease symptoms and strategies for disease management are presented and strategies for future work are outlined. As such, Pathogen Profiles are an ideal vehicle to deliver our resources to the scientific community.

Some important xanthomonads have been recently described in Pathogen Profiles, such as the citrus canker agents *Xanthomonas citri* subspp. *aurantifolii* and *citri*, the bacterial spot pathogen of stone fruits and almond, *Xanthomonas arboricola* pv. *pruni*, and the bacterial leaf streak pathogen of cereals, *Xanthomonas translucens* pv. *translucens* (Ference et al., 2018; Garita-Cambronero et al., 2018; Sapkota et al., 2020). Another genetically related pathogen, *Xylella fastidiosa*, the causal agent of various economically important diseases, such as Pierce's disease of grapes (PD), citrus variegated chlorosis (CVC), and olive quick decline syndrome (OQDS), has also been covered recently (Rapicavoli et al., 2018). Moreover, this pathogen was the subject of a Focus Issue in the APS journal *Phytopathology* (Almeida et al., 2019).

In a series of four Pathogen Profiles, we and others address several xanthomonads that are listed on the A1 and A2 lists of the European and Mediterranean Plant Protection Organization and have not been discussed recently (Figure 1). Both lists contain pathogens that are recommended to its member countries to be regulated as quarantine pests. Pests of the A1 list are absent from the EPPO region, whereas pests of the A2 list are locally present in the EPPO region. In addition, we complement this set of pathogens with a Pathogen Profile about cassava-infecting xanthomonads because of their important socioeconomic impact worldwide.

1. *X. citri* pv. *fuscans* and *Xanthomonas phaseoli* pv. *phaseoli* are the causal agents of common bacterial blight of bean (CBB), an important disease worldwide that remains difficult to control (Chen et al., 2021). These two bean pathogens belong to distinct species within the *Xanthomonas* genus and have undergone a dynamic evolutionary history, including the horizontal transfer of genes encoding factors probably involved in adaptation to and pathogenicity on common beans. Seed transmission is a key point of the CBB disease cycle, favouring both vertical transmission of the pathogen and worldwide distribution of the disease through global seed trade.
2. The species *Xanthomonas arboricola* comprises up to nine pathovars, two of which affect nut crops: pv. *juglandis*, the causal agent of the bacterial blight, brown apical necrosis, and the vertical oozing canker of Persian (English) walnut, and pv. *corylina*, the causal

FIGURE 1 Participants in the Pathogen Profiles Workshop at the COST Association headquarters in Brussels, Belgium. From left to right: Jens Boch (Germany), Joana G. Vicente (UK), Fernando Tavares (Portugal), Monika Kałużna (Poland), Jan van der Wolf (Netherlands), Marie-Agnès Jacques (France), Ralf Koebnik (France), Emilio Stefani (Italy), Bart Cottyn (Belgium), Joël F. Pothier (Switzerland), and Nicolas W.G. Chen (France)

agent of the bacterial blight of hazelnut (Kałużna et al., 2021). These two pathovars constitute the most serious threats for walnut and hazelnut trees, respectively. Recently, a new species of xanthomonads colonizing walnut trees, named *Xanthomonas euroxanthea* after our COST Action, was discovered that we will relate to the previously described pathogens of the species *X. arboricola*.

3. Bacterial spots on tomato and pepper are caused by three *Xanthomonas* species: *Xanthomonas euvesicatoria* (pvs *euvesicatoria* and *perforans*), *Xanthomonas vesicatoria*, and *Xanthomonas hortorum* pv. *gardneri* (Osdaghi et al., 2021). This group of pathogens has undergone several taxonomic revisions that are not yet generally accepted in today's literature. The key milestones in research and management of bacterial spot diseases are nicely illustrated in a century-wide timeline, which will help newcomers to the field to better grasp the older literature.
4. Cassava bacterial blight is a severe disease caused by *X. phaseoli* pv. *manihotis* (Zárate-Chaves et al., 2021). The disease is characterized by a range of symptoms that affect mainly leaves, petioles, and stems, which eventually can lead to plant death. Cassava bacterial necrosis is another disease of this crop, caused by another *Xanthomonas* species, *Xanthomonas cassavae*, that, despite being characterized by symptoms that might be similar at first sight, has an infection outcome that is not as devastating as those caused by *X. phaseoli* pv. *manihotis*.

A fifth manuscript on the *Xanthomonas hortorum* species is currently being prepared and will soon complete this series of Pathogen Profiles. This species currently comprises seven pathovars of *X. hortorum* (pvs *carotae*, *cynarae*, *gardneri*, *hederae*, *pelargonii*, *taraxaci*, and *vitians*). Members of this species cause bacterial blight and bacterial spot on important crops (e.g., artichoke, carrot, lettuce, tomato), ornamentals (e.g., ivy, pelargonium), and wild plants (e.g., dandelion). Moreover, *X. hortorum* strains have also been isolated from nonprimary symptomatic host plants such as peony, lavender, pot marigold, and avocado. One pathovar, *X. hortorum* pv. *gardneri*, has been classified in 2015 as an EPPO quarantine organism and as an EU-regulated nonquarantine pest since 2019.

By compiling knowledge on some of the most important xanthomonads we hope that this series of Pathogen Profiles will trigger new ideas and concepts for future efforts to understand and combat these pathogens. Open communication and collaboration among scientists, extension workers, seed producers, and other stakeholders, as impressively supported by the COST Programme, will pave the way towards more durable solutions for disease management.

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