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ECOLOGY

Can Apulia's olive trees be saved?

An introduced plant pathogen proves difficult to contain in southern Italy

By **Rodrigo P. P. Almeida**

On 21 October 2013, the Italian phytosanitary service notified the European Commission (EC) that the plant pathogen *Xylella fastidiosa* had been detected in olive trees near Gallipoli, a tourist destination in Italy's southern region of Apulia (1). This xylem-limited bacterium is spread by insect vectors and causes disease in crops such as grapevines, citrus, coffee, and almond; various ornamentals; and trees such as oaks, elms, and sycamores. Because of the risks of *X. fastidiosa* being introduced, established, and spread throughout Europe, this species is a regulated quarantine pest. Yet, *X. fastidiosa* has

been left unchecked and has marched northward, leaving destruction in its wake (see the photo) (2). The establishment of *X. fastidiosa* in Italy has been an agricultural, environmental, political, and cultural disaster.

The threat of *X. fastidiosa* to European and Mediterranean agriculture, forests, and ecosystems goes beyond specific crops such as grapevines or citrus. The current host range of this bacterium includes more than 300 plant species (3). Most of these species support some degree of pathogen multiplication without expressing symptoms. Susceptible hosts infected with *X. fastidiosa* often show disease symptoms only after months or years, although epidemics can spread fast and be devastating.

A phylogenetic study has shown that the genotype in Italy was likely introduced via contaminated plant material from Costa Rica (3). Several *X. fastidiosa*-infected coffee plants from Costa Rica have been intercepted at European ports since 2014, supporting this hypothesis (4). As a response, the EC in February 2014 approved European Union (EU) emergency measures aimed at preventing the introduction and spread of *X. fastidiosa*. Since May 2015, the import of coffee plants from Costa Rica and Honduras into the EU has been forbidden. Limiting the introduc-

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Irreplaceable trees. In this aerial view of an olive grove in the Salento peninsula, *X. fastidiosa*-infected trees show intermediate disease symptoms. Efforts to contain the pathogen's spread by cutting down infected trees have been hampered by local opposition.

tion of insect vectors is considered an easier task, but this is not possible for *X. fastidiosa* because any xylem-sap-sucking insect species can be a potential vector. Europe has few sharpshooter leafhopper species, the most important group of vectors in the Americas. However, various endemic spittlebug species (froghoppers) are also potential vectors of *X. fastidiosa* (3).

Trade is an important pathway in the introduction of plant pests and pathogens (5), and *X. fastidiosa*-infected plant material has likely been introduced via European ports on a regular basis. Given that biological and environmental conditions in Europe support *X. fastidiosa* infection, the question arises why the pathogen has not been reported previously. One possible explanation is that limited surveillance efforts missed previous introductions. Monitoring was one component of the EU emergency measures. After the French authorities started a systematic monitoring program for *X. fastidiosa* in 2014, they found 250 distinct infected areas

in Corsica and several in the French Riviera. However, no disease epidemic has yet been noted in France, and the genotype of *X. fastidiosa* differs from that found in Italy.

Control efforts of *X. fastidiosa* diseases in Brazil and the United States, where most economic losses due to this pathogen occur, rely on a combination of insect population suppression and removal of infected plant material. Initial management efforts in Italy and France were expected to follow legally binding EC decisions. These include elimination of infected plant material and other susceptible hosts within 100 meters, the use of treatments to suppress vector populations, and surveillance of a larger area surrounding each location where infected material has been found. France is following these regulations, but they have not been implemented in Italy.

Eradication of *X. fastidiosa* requires early diagnosis and a small infected area, and is no longer feasible in Apulia. The role of olive trees in pathogen spread remains to

be quantified, but they serve as a source of inoculum to spittlebug vectors (see the figure). Information required to manage the epidemic in Italy is being generated, such as new evidence of olive varietal tolerance to *X. fastidiosa* (6). But it remains unclear how long it takes for plants to develop symptoms after infection. A March 2016 report by the European Food Safety Authority indicates that it takes 12 to 14 months for small olive plants to show disease symptoms after artificial infection with *X. fastidiosa* in greenhouses (7). This is relevant because vectors may acquire *X. fastidiosa* from an infected host prior to developing symptoms. Eliminating diseased trees may thus have limited impact on containing the pathogen. Instead, removing infected yet asymptomatic plants surrounding sick trees may be key to controlling disease spread. It is likely that the epidemic is more prevalent than suggested by symptomatic trees, and the pathogen may already be present north of the current containment line.

Local environmentalists and politicians have challenged EC decisions and have used lawsuits to block attempts to manage the epidemic (2). Their efforts to protect olive trees by blocking containment strategies have, however, only exacerbated the problem. Public distrust of science and scientists has led to conspiracy theories that have permeated local society, further hampering control efforts. In retrospect, social turmoil should have been expected given the prominent role of olive trees in Apulian culture. Olive trees are tightly linked to its people; it is their heritage, an indivisible part of who they are. In addition, ubiquitous olive trees are a key attraction of an economically important tourism industry, provide income to rural communities, and are a keystone species in the ecosystem. The EC aims to address the threats of *X. fastidiosa* as a plant pathogen, demanding management and containment measures. But the reality to Apulians is different: Cutting down their olive trees means destroying the physical embodiment of their families and history. Here, the disease is killing irreplaceable trees, including those planted to mark the births of family members for generations. The harm to Apulian culture and society is perhaps beyond quantification.

Reconciling technical and political differences will be key to limiting the impact of *X. fastidiosa* to Apulia and Europe at large.

It remains to be seen whether a 9 June 2016 ruling of the European Court of Justice, determining that EC-mandated control measures were legal, will be accepted locally. Implementation of the ruling would suggest that there is hope in limiting pathogen spread, but time is running out for the olive trees in Apulia. The reluctance of political leaders to quickly take required but unpopular decisions, in addition to a judicial system slow in responding to an emergency, are likely responsible for the current lack of substantial action in controlling the epidemic. There has also been limited local political support for scientists, who are

trade and biological invasions may need to be better explored (11), and control of the pathogen at the source rather than destination may be more effective.

An important lesson from the *X. fastidiosa* epidemic is that strategies to manage diseases of socially important plants must go beyond technical solutions and incorporate social, economic, political, and cultural components. In the case of *X. fastidiosa* in Italy, implementation has been the bottleneck as these diverse stakeholders did not cooperate. Models for such cooperative structures have been proposed (12). Rapid reaction time is key to success in manag-

Pathogen spread. The epidemiology of *X. fastidiosa* infecting olive trees in Apulia is still poorly understood. The prevailing hypothesis proposes that olive trees are the main pathogen inoculum source, and that tree-to-tree *X. fastidiosa* spread occurs once insect vectors move to trees from drying ground vegetation.

unable to freely seek answers to important epidemiological questions because of restrictions on field experimentation; even disease monitoring has been blocked (8).

The introduction of plant pathogens and pests is a growing risk to ecosystems and societies (9), but not a new one. The potato famine in Ireland, blight of American chestnut in the USA, and grapevine phylloxera in France are examples of diseases and pests that have reshaped landscapes and cultures. Swift management strategies can lead to eradication or effective containment and long-term sustainable solutions. Global strategies to manage emerging disease and pest problems may be required, as have been proposed for planted forests (10). International trade regulations represent an opportunity to limit the introduction of novel pests, but the relationship between

ing outbreaks, unfortunately building trust among stakeholders to solve environmental problems often requires years. ■

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MICROBIOME

Is triclosan harming your microbiome?

Studies on the effects of a widely used antimicrobial reach conflicting results

By Alyson L. Yee^{1,2,3} and Jack A. Gilbert²

Antibacterial soaps were originally used only in hospitals, but since the 1990s, their use has expanded into households. Antimicrobial chemicals are now found in many soaps, wipes, hand gels, cutting boards, detergents, cosmetics, and toothpastes, as well as toys and plastics. One of the most common antibacterials, triclosan [5-chloro-2-(2,4-dichlorophenoxy)phenol], is found in ~75% of antibacterial soaps (1). In 2008, it was detected in ~75% of urine samples in the United States (2). There are concerns that triclosan use contributes to the development of antibiotic resistance and may adversely affect human health. Partial bans exist in the European Union and the U.S. state of Minnesota (3, 4). However, recent studies exploring triclosan's effect on the microbiome have given conflicting results.

Triclosan works by inhibiting the final step of the bacterial fatty acid synthesis pathway. At low concentrations it stops microbial growth, but at high concentrations it is bactericidal. Bacterial resistance to triclosan is readily obtained in the laboratory, but it is not clear that resistance is widespread in the environment. A 10-year study of triclosan exposure found no change in the antibiotic tolerance of methicillin-resistant *Staphylococcus aureus* or *Pseudomonas aeruginosa* (5). However, in a recent report, prolonged treatment with triclosan produced clinical resistance to ampicillin and/or ciprofloxacin in *S. aureus* and *Escherichia coli* (6).

To explore the effectiveness of triclosan, Kim et al. (7) recently compared the bactericidal effects of plain and triclosan-containing soaps under conditions that mimic

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