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EDITORIAL

Special issue on bacterial citrus diseases: part I

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Modern citrus species, believed to be native to the subtropical and tropical regions of Southeastern Asia, are currently present in more than 140 countries. However, the largest commercial citrus areas are in the Americas where they were firstly introduced by Spanish and Portuguese explorers during the seventeenth century (Liu et al. 2012). It took a couple centuries, precisely after World War II, for a large industrial park to establish when the production of frozen concentrated orange juice was pioneered by the US Department of Agriculture in Lakeland, Florida.

The new product was responsible to establish a powerful citrus industry in Florida and position the USA in the global leadership during the following decades (Hamilton 2003). A series of frosts affected Florida during the 1970s and 1980s, severely affecting citrus production. Then, a growing industry in Brazil took the opportunity to supply the needs of a large international market Miller and Glantz (1988). Nowadays, Brazil is the largest producer of sweet orange (*Citrus sinensis* Osb.) grown for export of frozen concentrated juice (Neves et al. 2017). In the USA, bacterial diseases have tremendously impacted citrus production during the last 20 years causing disastrous and likely irreversible impact on the business (Gottwald 2007).

The same warmer climate that provides citrus with the most suitable environment for fruit yield and quality also favors the occurrence of pests and diseases, most notably bacterial diseases that thrive in warm and humid weather and are difficult to control (Hirano and Upper 1983). Over the last century, outbreaks caused by a handful of bacterial diseases have caused tremendous losses to citrus production (Gottwald 2007; Mendonça et al. 2017). The scientific community has been called out, and research to understand and control bacterial diseases in citrus has received a great deal of attention. The most innovative and impacting research have been conducted by research groups based at research and academic centers in the major citrus areas financially supported by both public and private sectors. Extensive sharing and collaboration among international research groups have been essential to advance citrus pathology science, particularly on bacterial diseases. In fact, a bacterial citrus pathogen, *Xylella fastidiosa*, the cause of citrus variegated chlorosis (CVC), was the first plant pathogen ever to have its full genome sequenced by Brazilian scientists working collaboratively in more than 200 national laboratories. Early highlighted in the scientific media (Bonalumé 1997), the genome was finally published in the year 2000.

Bacterial diseases do not stop spreading and evolving, especially in a globalized world. During the last two decades, they keep expanding geographic range, adapting to new environments and challenging researchers to develop more effective, efficient, and durable solutions. A wealth of research on bacterial citrus diseases has impacted the field and provided basic knowledge applicable to other pathosystems, but several challenges remain. Some diseases that have been under control in the past, such as citrus canker, have reemerged due to changes in the management practices. Newly introduced ones in the America, such as huanglongbing (HLB, also known as greening), have shown devastating effects and keep spreading in a pace that the citrus industry struggles to contain (Gottwald 2010).

Two years ago, we envisioned the need to bring together review articles on bacterial citrus diseases to compose one of the special issues of *Tropical Plant Pathology*, the journal of the Brazilian Phytopathological Society (*Sociedade Brasileira de Fitopatologia*). Today, we are delighted to present not only reviews by leading scientists but also original research submitted voluntarily. The response to the call was so great that

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an initially planned single thematic issue became two! More than 30 submissions have been handled and mobilized half dozen editors and several dozen reviewers from all over the world. Given the current importance, HLB is the most frequently addressed disease in the articles, followed by citrus canker. In Brazil, CVC disease, previously of much greater importance, has been managed successfully and thus allow researchers to shift their attention to emergent problems.

Our first article is not focused on a disease. It provides a quantitative overview of the global consumption of frozen concentrated orange juice (FCOJ) in comparison with other flavors and beverages. The worldwide expert Prof. Neves and his collaborators stress the need to keep up with the current supply of amount and quality of fruit to keep Brazil in the leadership of the global trade, which of course depends on managing bacterial diseases successfully.

Historically, bacterial citrus diseases such as canker, CVC (only in Brazil), and HLB have caused a tremendous impact on the amount and quality of citrus production. Our second article by Coletta-Filho et al. deals with a disease that has been of great importance to Brazil: CVC. The authors present a comprehensive review on the etiology, epidemiology, and successful management of CVC caused by *Xylella fastidiosa* subsp. *pauca* and the associated vectors (sharpshooters from Cicadellini and Proconiini tribes). The other article on CVC in part I is an original research article (last of the issue). The broad picture of the elements responsible by generation of genetic variability and competitive advantages, the plasmids, in *X. fastidiosa* was studied by Pierre et al. Of all plasmids, 66% were conjugative, and the stability of others was believed as advantage of toxin/antitoxin systems.

We then continue with the reemerging citrus canker. Its current status in the USA is nicely summarized by Gochez et al. who show maps for Florida and Louisiana, where type A strain is present, and for Texas where only the type A^w has been reported so far. In the endemic areas of Florida, the disease has been managed with the integrated use of windbreaks, systemic resistance inductors, and copper-based molecules. The sensitivity of *Xanthomonas citri* strains to copper as well as the emergence of resistance to this bactericide is addressed by Behlau et al. The authors stress the need of new strategies and molecules for the citrus canker control, a topic that is thoroughly reviewed by Martins et al. The new and promising tools, such as genetically engineered plants, new chemicals, and biological control, are covered in two reviews. The association between biofilm formation and resistance of bacteria to antimicrobial compounds has been previously demonstrated, but Sena-Vélez et al. further show that the narrow-host range A^w strain produces less biofilm formation compared with broad-host range type A strain. Such behavior is associated with low expression of fimbrial and flagellar genes that, in some cases, is dependent on the quorum-sensing system.

The biggest challenge to citrus pathologists is the huanglongbing (HLB) disease, also known as citrus greening disease in some regions. Three reviews update on the current status and strategies employed for managing HLB in Brazil, USA, and China where '*Candidatus* Liberibacter asiaticus' (CLas) is the cause of HLB. This bacterium is vectored by the phloem-feeding insect *Diaphorina citri*, and no genetic resistance is known in the *Citrus* genera until now. Genetic engineering approaches are promising to enhance host resistance in the future, as reviewed by Soares et al. For diseases where the vector plays an important role in the epidemics, all links and interactions between host-plant-vector need to be considered. Knowledge of the incubation and latency periods for transmission of the pathogen is a key for the understanding of the epidemics. Canale et al. report incubation periods ranging from 2.5 to 5 months in citrus seedlings and citrus nursery plants, respectively. CLas acquisition by the vector occurred up to 2.5 months after inoculation or before symptom appearance. Understanding of the mysterious CLas with a focus on its virulence factors (secretion systems, effectors, pilus, and flagellar apparatus) and uses of chemical, physical, and biologic control were reviewed by Andrade et al. The authors further discuss a range of methods focusing on chemical, biological, and biotechnology strategies targeting the vector as well as the plant with nutritional programs, plant defense inducers, genetic resistance, and biotechnology strategies.

The use of RNA interference (RNAi) technology is one of the most promising strategies owing to its high target specificity. It relies on the delivery of exogenous double-stranded RNAs (dsRNAs) that target essential genes in insects. A comprehensive review of the RNAi literature and the potential use and challenges for *D. citri* control was documented by Yu and Killiny. Both the target genes and the dsRNA delivered are critical steps. A known strategy of citrus tristeza virus (CTV) infectious clone as a vector to deliver RNAi in phloem targeting *D. citri* was used by Killiny to study the interaction of CTV and CLas. Imbalance on the population of both systemic pathogens was related to environmental conditions of host such as nutrient supply. As already shown previously, no vertical transmission of CLas from seeds to seedlings occurred as reinforced by Bagio et al.

We hope this first group of articles, more packed with reviews, is of value for the scientific community and stakeholders with either broad interest on the impact of bacterial diseases to production or specific interest in research advances in the field. Part II is forthcoming packed with more original research and a few other reviews.

References

Bonalumé R (1997) Brazil to sequence 'first plant pathogen'. Nature 389: 654

Gottwald TR (2007) Citrus canker and citrus huanglongbing, two exotic bacterial diseases threatening the citrus industries of the Western Hemisphere. Outlooks on Pest Management 18:274–279

Gottwald TR (2010) Current epidemiological understanding of citrus huanglongbing. Annual Review of Phytopathology 48:119–139

Hamilton S (2003) Cold capitalism: the political ecology of frozen concentrated orange juice. Agricultural history. 1:557–581

Hirano SS, Upper CD (1983) Ecology and epidemiology of foliar bacterial plant pathogens. Annual Review of Phytopathology 21:243–270

Liu Y, Heying E, Tanumihardjo SA (2012) History, global distribution, and nutritional importance of citrus fruits. Comprehensive Reviews in Food Science and Food Safety 11:530–545

Mendonça LBP, Zambolim L, Badel JL (2017) Bacterial citrus diseases: major threats and recent progress. Journal of Bacteriology and Mycology Open Access 5:00143

Miller KA, Glantz MH (1998) Climate and economic competitiveness: Florida freezes and the global citrus processing industry. Climatic Change 12:135–164

Neves MF, Trombin VG, Kalaki RB (2017) Peeling back the citrus in Brazil: mapping and quantification of the Brazilian citrus chain. Citrus Research & Technology 35:45–60

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