

## Why is it so difficult to control Huanglongbing (HLB)? Point of view

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**ABSTRACT:** Sweet orange is an important fruit crop in several countries in tropical and subtropical regions. However, a devastating disease, Huanglongbing (HLB), threatens its production. This disease is associated with the bacterium '*Candidatus Liberibacter asiaticus*' (CLas), transmitted by the Asian citrus psyllid. This text examines the intricate relationships between host, pathogen, vector, and environment factors that complicate HLB control. It also reviews potential strategies, such as searching for resistance varieties, and discusses recommended HLB management, including eradication and preventive measures, while highlighting the difficulties in implementing effective management. This text points out the urgent need for innovative and integrated approaches to slow the progression of HLB and mitigate its impact on global citrus production.

**Keywords:** HLB epidemic, integrated HLB management, citrus disease, disease control strategies, vector-borne disease

### Introduction

Controlling HLB has long been one of the most significant challenges facing the global citrus industry. HLB is mainly associated with the bacterium '*Candidatus Liberibacter asiaticus*' (CLas), which is transmitted by the Asian citrus psyllid, *Diaphorina citri*. The disease manifests itself through symptoms in the leaves, roots, and fruit, resulting in reduced fruit quality, severe fruit drop, and, ultimately, the decline of infected trees. HLB was first detected in the state of São Paulo, Brazil, in 2004 and subsequently in Florida, USA, in 2005 (Graham et al., 2024). At that time, the São Paulo/Triângulo Mineiro (SPTM) citrus belt produced approximately 378 million boxes of sweet oranges (*Citrus × sinensis* [L.] Osbeck), while Florida produced around 150 million boxes. However, 20 years later, the impact of HLB is evident: by the 2023/24 season, SPTM's production had decreased to around 307 million boxes, and Florida's production had plummeted to just 18 million boxes. While environmental factors, such as hurricanes and freezes in the USA and severe heat waves and droughts in Brazil, have contributed to this decline, the impact of HLB remains a dominant factor. In Florida, the number of fruit-bearing trees has decreased by almost 60 %, primarily due to growers becoming discouraged by the difficulty of controlling the disease and the challenges of establishing new orchards in an HLB endemic area. In contrast, citrus growers in Brazil have continued to plant new orchards, employing various strategies to prevent HLB. This article will explore these strategies alongside the specific aspects of the host-pathogen-vector-environment interaction, which complicate efforts to control HLB.

In addition to sweet orange cultivars, HLB-bacteria colonize and induce symptoms and damage in all citrus species, including tangerines (*Citrus reticulata*

Blanco), lemons (*C. × limon* [L.] Burman f.), limes (*C. × aurantiifolia* [Christmann] Swingle), and grapefruits (*C. × aurantium* var. *paradisi* [Macfadyen] Ollitrault, Curk & Krueger). This broad host range complicates the search for resistance traits in commercial cultivars, which hinders the potential for HLB management through the use of resistant varieties. However, research has shown that two Australian-New Guinea genera – former *Eremocitrus* and *Microcitrus* – exhibited reduced or no bacterial multiplication, offering a potential avenue for resistance. As a result, one branch of research focuses on developing resistant hybrids by crossing these Oceanic species with commercial citrus cultivars. Moreover, understanding the physiological mechanisms that confer resistance to HLB on these species could contribute to future advances in biotechnology. Nevertheless, the development of a commercially viable resistant or tolerant cultivar may take considerable time.

Sweet orange trees are perennial plants with an expected productive lifespan of over 20 years. Therefore, one of the primary goals in HLB-affected citrus orchards is to cure infected trees. However, the effectiveness of therapeutic measures is limited by the fact that CLas colonizes the phloem sieve tubes and rapidly spreads from the inoculation site in the new shoot to the root system. Phloem colonization complicates the treatment of HLB-infected trees, as it is challenging to deliver antimicrobial agents to these vascular tissues and achieve uniform distribution throughout the tree, particularly in mature, bearing trees. Trunk injections of the antibiotic oxytetracycline have been widely tested in Florida orchards. However, the results have often been inconsistent, depending on the tree size and HLB severity, and are typically short-term in nature. Heat treatment and pruning of HLB-symptomatic branches are also ineffective, as these methods may eliminate bacteria from the aerial parts of the plant but not

from the root system. After branch removal or canopy thermotherapy, bacteria are often redistributed from the root system to the shoots via the phloem. The absence of effective therapeutic measures underscores the critical need for preventive strategies, such as evasion, exclusion, eradication, and protection.

HLB management focuses primarily on preventing the acquisition and transmission of CLAs by its vector. One strategy to reduce bacterial acquisition is the eradication of diseased trees, both within commercial orchards and in surrounding areas, such as non-commercial citrus orchards, backyards, and pastures. These sources of inoculum contribute to both primary and secondary infections: primary infections occur when the inoculum source is outside the orchard, while secondary infections arise when infected plants within the orchard act as inoculum sources. However, total eradication of HLB is not feasible once the disease has been introduced into an area due to several factors: (i) the contribution of primary spread, involving long-distance dispersal of the psyllid and multiple inoculum sources outside commercial orchards; (ii) the short latent and long incubation periods of HLB, which means that by the time symptomatic trees are detected, they have already served as inoculum sources for some months; (iii) the difficulty of detecting all infected trees through visual inspections or even quantitative polymerase chain reaction (qPCR), as infected trees often have uneven bacterial distribution, making it challenging to identify which branches to sample; and (iv) the reluctance of growers to remove diseased but still bearing trees.

Secondary infections can be effectively controlled through the eradication of HLB-symptomatic trees and biweekly insecticide applications in the orchard. The goal of biweekly spraying is twofold: (i) to prevent psyllid nymphs originating from infected trees from maturing into adults that carry the HLB bacteria, thereby disrupting the egg-to-adult psyllid cycle, which ranges from 12 to 45 days and (ii) to prevent adult psyllids that have recently acquired the bacterium from transmitting it, as the latent period in the vector ranges from 9 to 15 days. Controlling primary infections is significantly more challenging; however, specific strategies that consider the host's phenology, psyllid behavior, and vector dispersal can help reduce the rate of primary infection.

An important and specific aspect of the host-vector relationship is the high preference of the psyllid for new shoots, particularly at vegetative stages from V1 (bud swelling) to V4 (unfolding of all leaves). During these stages, the CLaV vector seeks out new shoots for oviposition and feeding. As a result, higher oviposition rates, nymph development, and bacterial transmission occur during these vegetative stages compared to later stages, such as V5 (light green leaves fully expanded) and V6 (dark green leaves). The complexity of the HLB pathosystem is exacerbated by uneven sprouting in the orchard. This process begins with the observation

of significant leaf defoliation in trees severely affected by the disease. As the rainy season begins, these diseased trees sprout approximately one week earlier than healthy trees. Consequently, psyllids disperse in search of new shoots and initially find those on diseased trees, which they may then spread to healthy trees in the following weeks if not adequately controlled. Additionally, the sprouting pattern varies between regions with high temperatures and water deficits and those with milder temperatures and lower water deficits. This variation implies that the environment can influence HLB management. In regions with higher temperatures, climatic conditions may aid in disease control as the shoots mature faster, thereby reducing the infection window. In contrast, in regions with continuous sprouting due to milder temperatures, trees remain susceptible for a longer period, necessitating extended shoot protection. Furthermore, in regions with well-defined dry and rainy seasons, shooting periods are more homogeneous and shorter. In contrast, in regions with a rainier climate, shooting is more frequent and lasts longer.

The psyllid's preference for early vegetative stages underscores the critical role of new shoots in the HLB epidemic. However, this also complicates HLB control, as continuous protection of new shoot tissues is required. Systemic insecticides applied via drenching are absorbed by the roots and redistributed throughout the tree, following shoot growth and providing protection. These insecticides are most effective in citrus trees up to 2 m tall (approximately three years old). Beyond this stage, the use of systemic insecticides becomes less economically viable and efficient, and psyllid control relies on foliar sprays. When applied to leaves, systemic insecticides act more as contact insecticides since they do not redistribute throughout the tree. Contact insecticides have shorter residual periods compared to systemic insecticides due to factors such as light degradation, temperature, and precipitation. Furthermore, when insecticides are applied at the V1 to V4 stages, the protection is less effective than when sprayed on at the V5 and V6 stages, as shoots grow rapidly during the early stages, with approximately three to four days between stages. In the absence of rainfall, the later stages remain protected for up to 14 days, while the early stages are only protected for less than seven days post-application. Infectious psyllids can transmit the bacterium in less than one hour of feeding, raising the question of whether spraying every three days during the sprouting period is necessary and feasible to prevent continuous primary infections. Additionally, growers must ensure uniform spray coverage across the entire tree, including the top third, and rotate insecticide modes of action to prevent the selection of resistant psyllid populations.

Asian citrus psyllids are capable of dispersing over long distances through short flights or by being carried on wind currents for several kilometers. They can also be transported on citrus nursery trees, though this form

of transport is typically prevented through certified nursery production. However, the active dispersal of psyllids remains difficult to control. The primary dispersal pattern of the HLB vector follows a decreasing gradient from the orchard's edge to its center, with the first 200 m from the border concentrating 80 % of the migrant psyllid population (Sétamou and Bartels, 2015). This pattern mirrors the spatial distribution of eradicated diseased trees, which also follow a decreasing gradient from the orchard edge to the center (Gasparoto et al., 2018). This information can be leveraged to guide HLB management efforts, particularly in the first 200 m of the orchard, which is more challenging to control. In addition to the more frequent application of insecticides in this edge strip, other strategies have already been recommended, including: (i) monitoring the psyllid population with yellow sticky traps along the orchard edge; (ii) planting large, square plots, as smaller and narrower plots result in a larger edge area; (iii) avoiding planting in highly fragmented areas to minimize the edge area; (iv) implementing high-density planting in the first 200-m strip; (v) orienting plant rows parallel to the orchard edge; (vi) using combinations of scion/rootstock with greater vigor at the edge; (vii) planting trap crops, such as orange jasmine (*Murraya paniculata* [L.] Jack) or curry (*Berbera koenigii* [L.] Sprengel), that attract psyllids but exhibit little or no bacterial multiplication, and applying systemic insecticides to these trap crops; and (viii) applying kaolin to specific rows to concentrate psyllid populations on the first trees while providing a repellent effect on trees farther along the row.

The need to protect the early vegetative stages of trees throughout their lifespan, coupled with the continuous primary infection, highlights the difficulty in achieving effective HLB control by solely eliminating symptomatic trees and applying insecticides in the orchard. Consequently, the exclusion strategy – reducing both the inoculum source and vector population outside the orchard – becomes crucial. Managing the broader area surrounding the orchard can decrease the number of external psyllids carrying the bacterium, resulting in a delayed onset of the HLB epidemic, a reduced infection rate, and a lower incidence of HLB (Bassanezi et al., 2013). This regional approach to HLB management, which combines efforts within orchards and in neighboring areas, has proven effective. For example, growers within the SPTM citrus belt who organized into regional groups observed a reduction in HLB incidence in their orchards. However, its implementation is challenging, as its success relies on the cooperation of all citrus growers in the region, as well as citrus plant owners in non-commercial areas.

In the past two years, due to the difficulty of controlling HLB, some growers have adopted the principle of evasion by starting to plant in areas surrounding the SPTM citrus belt, where HLB incidence is either absent or extremely low. According to data from the Coordenadoria de Defesa Agropecuária do Estado de

São Paulo (CDA-SP), in 2022 and 2023, 9 % of the total nursery plants produced in the state of São Paulo were allocated to other states, including Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, and Paraná, making a total of approximately 3 million nursery trees. Since HLB has already been detected in all of these states except Mato Grosso, it is essential to adopt area-wide HLB control strategies with coordinated actions among citrus growers. Without these joint efforts, it is only a matter of time before HLB reaches epidemic proportions in these new regions.

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## Authors' Contributions

**Conceptualization:** Bassanezi RB, Primiano IV, Bergamin Filho A. **Writing - original draft:** Primiano IV. **Writing - review & editing:** Bassanezi RB, Bergamin Filho A.

## Conflict of interest

The authors declare no conflict of interest.

## Data availability statement

There is nothing to declare. The contents underlying the manuscript are available within the literature.

## Declaration of use of AI Technologies

The authors declare that AI technologies were not used in the production of this manuscript.

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