The Battle Against Citrus Greening Disease

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Citrus greening disease, often known as Huanglongbing (HLB), is one of the most serious threats to the global citrus sector today. Because of its relentless expansion and fatal repercussions, the fight against this pernicious plant disease has escalated in recent years. Citrus greening, a bacteria-related disease caused by *Candidatus Liberobacter asiaticus*, is known for its capacity to weaken citrus trees, diminish fruit production and devastate once-thriving orchards. The Asian citrus psyllid (*Diaphorina citri*), a small insect vector responsible for disease transmission as it feeds on citrus plants, complicates matters further. The effects of citrus greening extend well beyond agricultural lands. This disease not only offers significant economic risks to citrus growers and the citrus-based economy, but it also affects the livelihoods of millions of people who rely on citrus farming for income and nutrition. Furthermore, it jeopardises the availability of this popular fruit in worldwide markets, raising worries about food security (Hung *et al.*, 2004).

Citrus greening disease has its origins in Asia, where it has been present for generations. The disease's first mention dates back to the late 1800s in China, where it was known as "huanglongbing" or "yellow dragon disease," a name derived from the characteristic yellowing of leaves in affected citrus trees. During the disease's first discovery, most research was conducted in its native Asian habitat, albeit full investigations on its causal agents were initially limited. Citrus greening arrived in the United States in the early 2000s, initially appearing in Florida in 2005 (Nguyen *et al.*, 2023) and then spreading to other citrus-producing regions. The disease is thought to have entered the United States via the transportation of infected plant material or the movement of infected Asian citrus psyllids, small insects that serve as primary vectors for the bacterium CLas, which is responsible for disease transmission when feeding on citrus trees. Citrus greening has spread fast since then, crossing continents and becoming a global agricultural threat. The worldwide mobility of diseased plant material and psyllids has aided its global spread, emphasising the necessity for a full study of its origins to inform the ongoing battle against this devastating citrus disease.

To protect the future of citrus agriculture worldwide, efforts to prevent citrus greening have increased, with an emphasis on producing resistant citrus cultivars, implementing effective vector control measures and developing early detection tools.

Economic and Agricultural Impact: Citrus greening has a significant economic and agricultural impact. Fruit yield and quality are reduced in infected plants, resulting in considerable economic losses for citrus growers. In severe cases, sick trees become unproductive and must be destroyed, compounding financial difficulties. The disease has put citrus growers and the citrus-based industry's livelihoods in risk.

Global Spread and Efforts to Combat: Citrus greening has expanded fast from its Asian roots to citrus-growing countries around the world, necessitating coordinated efforts to reduce its impact. These efforts include the development of disease-resistant citrus varieties, the implementation of strict quarantine procedures to prevent the spread of contaminated material and the use of integrated disease management tactics to control the Asian citrus psyllid population.

Detection

Visual Symptoms Inspection: Visual inspection is one of the most accessible approaches for diagnosing citrus greening. Pathologists and producers inspect citrus trees for symptoms such as asymmetrical browning of the leaves, known as chlorosis and the occurrence of mottled, deformed and bitter fruit. Visual examination provides an early sign of infection and directs subsequent diagnostic steps.

Polymerase Chain Reaction (PCR) Testing: PCR is a molecular technique used to detect the presence of the citrus greening-causing bacterium CLas. DNA is retrieved from leaf samples gathered from potentially affected trees. CLas DNA is amplified using PCR, allowing it to be detected even at low amounts. This approach has a high specificity and sensitivity, making it a reliable diagnostic tool.

Immunological Assays: Immunological tests, such as enzyme-linked immunosorbent assays (ELISA), are used to detect specific proteins connected to CLas. These tests focus on the interaction of antibodies with CLas antigens to provide a quick and cost-effective diagnosis.

Nucleic Acid-Based Detection: Other nucleic acid-based detection technologies, such as loop-mediated isothermal amplification (LAMP) and quantitative real-time PCR (qPCR), have gained favour because to their speed and sensitivity in identifying CLas DNA. They are especially useful for large scale testing in commercial orchards (Tsai *et al.*, 2008).

Spectroscopy and Remote Sensing: New tools for detecting citrus greening include spectroscopy and remote sensing. These methods examine the spectral properties of citrus tree canopies in order to detect small changes associated with disease. Large-scale monitoring of orchards is possible because to hyperspectral and multispectral imagery, as well as unmanned aerial vehicles (UAVs) (Li *et al.*, 2014).

Electronic Nose Technology: Gas sensors in electronic nose devices can identify volatile organic chemicals released by sick citrus plants. These gadgets offer quick, non-invasive and potentially early disease detection.

Citrus Health Management Programmes: Several citrus-producing regions have comprehensive citrus health management programmes in place. These programmes include regular monitoring of orchards, prompt removal of sick plants and strict quarantine procedures to prevent disease spread.

Early diagnosis of citrus greening is critical for minimising economic losses and limiting its spread. The combination of different detection methods and ongoing research efforts continue to improve disease diagnosis accuracy and efficiency, providing hope in the ongoing battle against this powerful citrus crop pest.

Devastating effect on citrus crops

Citrus greening disease has wreaked havoc on citrus crops all over the world, leaving an indelible impact on citrus growers and the citrus sector as a whole. The consequences of this pernicious disease are multifaceted. It causes a significant decrease in fruit productivity and quality, with infected plants producing smaller, deformed and frequently bitter fruit. These yield losses, which range from 30% to 100%, place severe financial hardship on farms. Pest management initiatives, which include increasing pesticide applications to control the Asian citrus psyllid vector, raise production expenses, further reducing profitability. As citrus greening advances, infected trees health deteriorates, resulting in yellowing leaves, branch dieback and decreased yield. Many damaged trees become unviable and must be removed and replaced, adding to financial constraints. The economic toll affects entire regions that rely on citrus production, affecting revenue, employment and related industries, threatening livelihoods and community stability. Beyond regional borders, worldwide citrus supply chains are affected, resulting in higher prices and reduced fruit availability for consumers. Citrus farming's sustainability is under jeopardy, necessitating ongoing research, investments in disease-resistant cultivars and the use of integrated pest and disease management practises to ensure the industry's future. The continued fight against citrus greening is critical to preserving this important agricultural sector and its contribution to the global economy.

The Culprit: Asian Citrus Psyllid

The Asian citrus psyllid (*Diaphorina citri*) is at the heart of the citrus greening disease (Huanglongbing or HLB) catastrophe (Setamou *et al.*, 2023). This insect is about 3-4 millimetres long and has remarkable mottled brownish wings and a downward-sloping pointed head, adopting a

distinctive roof-like wing posture at rest for simple identification. Its tiny stature, however, betrays its significant significance as the major vector for HLB. While feeding on the phloem sap of infected citrus trees, infected psyllids pick up the bacterium *Candidatus Liberobacter asiaticus* (CLas). They carry CLas within their bodies once infected and further feeding on healthy citrus trees exposes the bacterium into the tree's vascular system, enabling HLB spread. The psyllid life cycle is divided into four stages: egg, nymph, pupa and adult. These stages are distinguished by the consumption of citrus sap, the release of protective waxy compounds and as adults, the potential transmission of HLB if infected. Because of its rapid reproduction and mobility, the psyllid is an effective HLB vector, demanding stringent management measures such as pesticides and integrated pest control to battle the disease's rapid spread and preserve citrus crops.

Management Strategies

A multimodal approach is required to effectively manage and control citrus greening disease (Huanglongbing). Regular orchard monitoring is critical for early detection, using optical surveys, pheromone traps and remote sensing technologies to identify sick plants and pest populations. Strict quarantine measures prevent the spread of infectious materials and pests across borders. The disease vector, the Asian citrus psyllid, must be managed using integrated pest control measures that include insecticides and natural predators. Infected trees should be removed and replaced as soon as possible to prevent further transmission. Disease-resistant citrus varieties are being developed through genetic alteration and traditional breeding (Alquezar *et al.*, 2021). Some growers use antibiotics and nutritional therapy to extend the yield of afflicted trees. Tree health is improved through improved nutrition and soil management practises. Compliance with control measures requires public knowledge and education. Continuous research and global collaboration promote innovation, providing optimism for the protection of citrus orchards and the industry's resilience in the face of this serious danger.

Innovative biological management tactics have taken front stage in the ongoing war against citrus greening disease, harnessing the prowess of beneficial insects and natural predators to tackle the Asian citrus psyllid, the major vector responsible for spreading HLB. These tactics include a variety of natural friends, such as ladybirds, whose ravenous hunger for psyllids and their nymphs aids in population control. *Tamarixia radiata*, a parasitoid wasp, lays its eggs within psyllid nymphs, eventually killing them and demonstrating substantial potential in psyllid management (Chen and Stansly, 2014). Lacewing larvae, which have a voracious appetite for small insects such as psyllids, are placed into orchards to help with population control. Predatory mites, such as *Amblyseius swirskii*, are effective against psyllid eggs and nymphs and certain bird species, such as the green lacewing bird, help in psyllid predation (Juan-Blasco *et al.*, 2012). Furthermore, conservation initiatives to encourage the presence of natural enemies, such as parasitoid wasps, include promoting habitat-friendly circumstances in orchards through diversified flora and reduced pesticide use. To maximise pest management, monitoring and targeted release programmes ensure that beneficial insects are deployed during important periods of the psyllid's life cycle. These biological control initiatives provide an environmentally beneficial and sustainable alternative to chemical pesticides, establishing balanced ecosystems inside citrus orchards and allowing growers to protect their citrus trees from the hazardous impacts of this citrus-devastating disease.

Conclusion

The citrus sector is contending with Huanglongbing (HLB) disease, which is transmitted by the Asian citrus psyllid. Despite the hurdles, the industry has deployed a variety of HLB-fighting techniques, including early diagnosis, monitoring and the development of disease-resistant cultivars. To reduce the disease's impact, quarantine procedures, integrated pest management and biological control activities are applied. Public awareness and education campaigns are very important in disease prevention and compliance. HLB has serious consequences for the

sector, including lower fruit yields, higher production costs and economic losses. These problems, however, have inspired the industry to explore new solutions, create worldwide collaboration and engage in research and development in order to safeguard the future of citrus cultivation. Despite the substantial hazards, the citrus industry is committed to safeguarding this key agricultural sector and ensuring that citrus fruits be enjoyed for future generations.

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