Transforming agriculture with solution-driven science

In recent years, the agricultural industry has faced unprecedented challenges due to emerging pests and diseases threatening crop production worldwide. **Dr Robert Shatters**, a research scientist at the **US Horticultural Research Laboratory**, discusses the transformative potential of solution-driven science in addressing agricultural crises and pushing the industry towards a more resilient and sustainable future.

Dr Robert Shatters

US Horticultural Research Laboratory, US Department of Agriculture, USA

Field of research
Molecular and cellular genetics

Research project
Restructuring the academic model to deliver solutions to emerging pest and disease issues in crop production

Funders
US Department of Agriculture (USDA), National Institute of Food and Agriculture (NIFA)

PROFILE

Talk like a ...

research scientist

Biosecurity toolbox — a set of guidelines and tools to prevent and respond to threats in agriculture

Huanglongbing (HLB) — a bacterial disease (also known as citrus greening disease or CGD) affecting citrus trees, leading to significant damage and eventual tree death

Phloem — the tissue in plants that transports sugars and other organic compounds produced by photosynthesis from the leaves to other parts of the plant

Symbiont™ platform — a method to deliver therapeutic molecules to citrus trees to combat HLB

Vascular system — the system of vessels (such as xylem and phloem) in plants that transport water, nutrients and other substances throughout the plant

Vector — an organism, often an insect or other animal, that transmits pathogens from one host to another

In today's agricultural industry, there is a pressing need to rethink our approach to scientific inquiry. As challenges such as emerging pests and diseases threaten crop yields worldwide, it becomes increasingly evident that traditional research models fall short of delivering timely and effective solutions. At the US Horticultural Research Laboratory, Dr Robert Shatters emphasises the urgent need to re-evaluate and reshape the existing ways of conducting science. His insights – along with those of the many scientists he collaborates with – highlight the importance of adopting innovative and collaborative approaches to address the complex and multifaceted challenges confronting the agricultural sector today.

The challenges

One challenge faced by the agricultural community currently is huanglongbing (HLB), sometimes called citrus greening disease – an example of the dire consequences that can arise without proactive and solution-oriented scientific approaches. HLB is a bacterial disease transmitted by insects that affects citrus trees (such as orange, grapefruit and lemon). "The bacterium lives in the plant's vascular system and is transmitted from plant to plant solely by the Asian citrus psyllid, a small insect that feeds on the vascular system, much like a mosquito feeding on our vascular system," explains

> **... traditional research models fall short of delivering timely and effective solutions.**

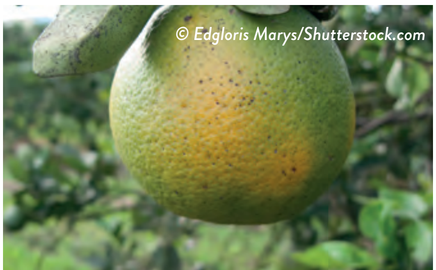
Robert. "It starts to damage the plant's vascular system and blocks movement of food from the leaves to the roots." This gradual damage weakens the tree, causing it to eventually die. As a result, it is very difficult for farmers to maintain healthy citrus trees and ensure a reliable fruit supply for consumers.

The insect responsible for spreading the bacteria causing HLB was first found in Florida in 1998. It was not until 2005 that people noticed the disease affecting citrus trees in the state. Unfortunately, when the tree becomes infected with the bacteria, it takes a long time for any signs of sickness to appear. "There is a long latency period of around two years, when the bacterium is dividing and moving systemically in the plant, but there are no visible symptoms of disease," says Robert. "Psyllids moved the bacterium all over Florida citrus crops for years before the disease was detected. When the disease *was* finally detected, it was too late to contain and eradicate it." Intense US research on this disease did not start until after it was discovered in 2005, even though it was a major threat to citrus trees worldwide for a long time. This delay meant that scientists had to start from scratch, conducting basic research to understand the disease better. The funding for this research followed the typical academic model, with lots of small research projects gathering basic information.

Florida's citrus industry is an example of the consequences of delayed action in the face of agricultural crises. More specifically, Florida's citrus production dropped by nearly 90% from 233 million boxes in 2000 to just 16 million boxes in 2023 – this is the collapse of a major horticultural crop. The citrus processing plants, packinghouses, and all associated industries (food, irrigation, equipment, harvesting) have also been impacted. While the disease is also present in California and Texas, its spread there has been slower. However, there are concerns within the industry that these states could suffer significant impacts in the future.

Current strategies

Efforts to fight HLB vary across states in the US. "In Florida, where the disease is widespread, they are trying different things like looking for more supportive rootstocks, using nutritional supplements and therapeutics to keep infected trees healthy, and controlling the Asian citrus psyllid vector," says Robert. "Meanwhile in California, the focus is on stopping the disease from spreading." This involves restricting the population of Asian citrus psyllids, destroying infected trees, and teaching people in the industry how to prevent it. Despite spending a lot of money (>$1.4 billion) on these efforts, the current approaches have not worked. "Intensive vector controlling activities did not reduce the spread in Florida, and nutritional treatments are costly, with average production costs increasing from $880 to $1875 per acre between 2004 and 2018 in the state," explains Robert. "Recently, many growers have started to inject trees with therapeutic molecules (i.e., oxytetracycline)." While this method has shown promise in improving tree health, it is not sustainable in the long term, and researchers need to find other ways to treat the disease so that the bacteria do not become resistant to current treatment options. These challenges show the complexity of combatting diseases such as HLB and the need for continued research and innovation to develop effective and sustainable solutions.



Huanglongbing (HLB) makes it difficult for farmers to maintain healthy citrus trees.

Global *agriculture*

The example of huanglongbing (HLB) is a warning sign for other agricultural problems. As trade moves more goods around the world and climate change expands the areas where plant diseases and the insects that carry them can thrive, similar challenges affecting other crops are expected.

Dr Randy Niedz

Research Geneticist, US Department of Agriculture, US Horticultural Research Laboratory

Dr Randy Niedz explains, "The same dynamics are almost certainly present in other systems. Coffee and cocoa crops have serious diseases of their own which will have the same effect: increased cost of production and higher costs to the consumer."

There are many known crop diseases currently in isolated areas that are being watched for their potential movement into major commodity production areas. Robert explains, "This is exacerbated by the global desire to move away from chemical pesticides that can be very effective but often have a negative impact on the environment." Without alternative biosecurity tools, these agricultural problems could become worse, putting global food production at risk. "If we see this as a war, we can then see the need to have multi-layered security that includes monitoring, surveillance, quarantine, eradication, and management practices," says Robert. "These practices need to be integrated and conducted on a global scale through international collaborations." A report by the United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services highlights the importance of the situation, revealing that invasive species cost the world around $423 billion every year.

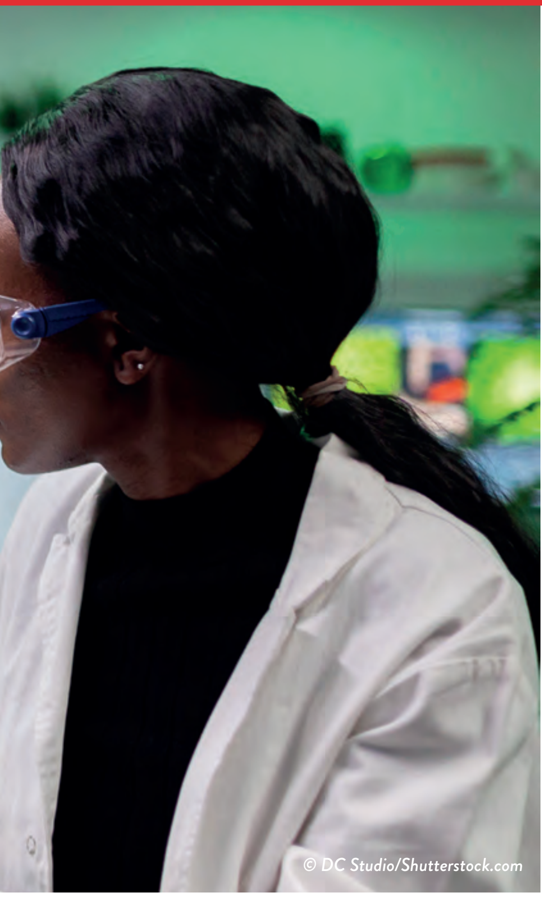
A call for a coordinated effort

To better address agricultural challenges, we need to rethink how research is conducted. "The 'academic model' for research is important, allowing diverse areas of research based on a broad spectrum of hypotheses to be conducted," says Robert. "The 'cast a broad net' concept helps in collecting diverse data on a specific topic, but also takes time, and often creates redundancies and other issues associated with a lack of focus." In the case of HLB, there was a crucial need for problem-solving research, but much of the funding was directed towards basic science. Research needs to transition towards coordinated, multidisciplinary projects where teams work together towards common goals, rather than individual projects operating independently.

At a bigger scale, dealing with agricultural challenges requires international cooperation. "Invasive species do not respect borders," says Robert. "Understanding the dynamics of the global situation with respect to emerging crop pest, pathogen and weed problems will allow a global targeting of solution-driven resources. This will address emerging issues before they spread to major agricultural production areas, and at the same time, create solutions to all sectors of the globe with respect to food security." This approach ensures food security for all and promotes worldwide economic well-being.

Moving away from the academic model

Moving to a more practical approach is essential for addressing agricultural challenges effectively. "It means defining the problem and what the relevant measures are – and involving all the related experts (including growers) in the experimental design planning," says Randy. "This more efficient approach means identifying treatments that have large effects (and that growers can use) and then using the academic model to understand how that treatment is working."



Dr Rodney Cooper

Research Leader, US Department of Agriculture

Dr Rodney Cooper highlights the potential for specific tools developed for one crop to be applied to different crops facing similar challenges. A great example of this adaptability is presented in the ongoing battle against cherry X-disease – an epidemic that has caused devastating economic losses exceeding $150 million in the cherry industry in the Pacific Northwest in recent years. “Cherry X-disease is caused by a plant pathogen called *Phytoplasma pruni* that is transmitted to plants by several leafhopper vectors that feed primarily on broadleaf weeds,” explains Rodney. “Like HLB, there are no cures for cherry X-disease, so growers must rely upon the use of insecticides to reduce vector populations.” With symptoms appearing approximately three years after initial infection, the disease spreads through orchards unnoticed. Farmers often have to remove whole infected orchards to stop it from spreading further. New fruit trees cannot be planted in those areas for another six years because there is still a risk of the new trees getting infected from old roots.

Drawing parallels with the early years of combatting HLB in Florida, researchers in the Pacific Northwest face a pressing need to develop practical solutions for cherry growers dealing with the X-disease epidemic. “Luckily, citrus greening research provides the researchers with research directions that will have the greatest return on investment,” says Rodney. “Specific tools like ‘Symbiont™’ and direct infusion of antibiotics may be directly adaptable for use against cherry X-disease.” Using the groundwork laid by HLB research, scientists can accelerate the adaptation and delivery of practical solutions to mitigate the impact of X-disease on cherry cultivation. (Learn more about Symbiont™ technology on page 8.)

The need for a biosecurity toolbox

Factors such as the increasing human population and the growing desire to limit reliance on synthetic pesticides highlight the need for innovative solutions provided by a biosecurity toolkit. Moreover, the increased global movement of agricultural goods increases the risk of introducing invasive species into new ecosystems, which makes the development of biologically-based alternatives necessary.

Human activities, particularly those related to global trade, contribute significantly to the introduction, and spread, of invasive species. “Insects, plants and pathogens often enter the US on shipping containers at major ports,” says Rodney. “The vast majority of these introductions are intercepted or fail to establish, but the minority that become established can cause enormous economic damage.” Invasive species can also exploit other pathways for introduction, including transportation on trains, trucks, and even through travellers carrying contaminated firewood.

The risks associated with invasive species are not always apparent at first glance. For example, the spread of an invasive plant species may accidentally facilitate the expansion of native insects into new territories, where they can emerge as major pests. At the same time, the introduction of a non-native insect could potentially transmit unknown pathogens from weeds to crops, exacerbating agricultural challenges. “A biosecurity toolbox provides a set of guidelines for solution-driven science and highly adaptable tools that can be deployed rapidly to prevent establishment and spread of invasive species,” explains Rodney. “It breaks the cycle of using huge amounts of funds to pool information and focuses research efforts on rapid responses to new problems.”

Climate change adds to the severity of the situation by changing the geographical range in which invasive species can survive. “Invasive species are often less susceptible to climate change than most endemic native species,” says Rodney. “If the temperature increases in an area, pests, pathogens and weeds that could not survive in that region before, can now thrive.” This greater adaptability to changing climates amplifies their competitive advantage, allowing them to flourish in diverse environments. This can disrupt existing pest management practices and make the challenges faced by agricultural systems worse.

The concept of a biosecurity toolkit addresses the constant threats from invasive pests and pathogens that can harm various agricultural and natural systems. A biosecurity toolkit offers a clear and structured plan to identify critical knowledge gaps quickly and provide adaptable, sustainable, and cost-effective tools for responding to these challenges. “The academic model tends to produce competing research interests and mountains of data without a clear direction for using that knowledge to develop practical solutions,” says Rodney. “Solution-driven science puts an emphasis not only on gathering key information but also on moving ‘pie-in-the-sky’ ideas out of laboratories and into the field.” By using existing technologies and adapting them to new contexts, the biosecurity toolkit facilitates the rapid development and implementation of solutions to fight emerging biosecurity threats.

Multidisciplinary *team building*

Dr Lorenzo Rossi

Root Biologist, University of Florida

Dr Laura Fleites

Project Leader, Agrosource Inc.

Dr James Thomson

Research Geneticist, US Department of Agriculture

In agricultural research, a wide array of disciplines converge to tackle complex challenges. Dr Lorenzo Rossi emphasises the importance of disciplines such as plant biology, chemistry, botany, horticultural sciences, tree physiology, molecular and cellular biology, plant pathology, agricultural engineering, plant breeding, and postharvest fruit physiology. This multidisciplinary approach is vital as researchers' combined efforts form the backbone of comprehensive problem-solving strategies.

Knowledge produced by the academic model is very important for understanding the complexities of agricultural challenges. Researchers need to comprehend the interactions between pathogens, plants and vectors, as well as the molecular pathways that facilitate invasion. "However, that knowledge is useful only if multidisciplinary teams communicate and work to mould that knowledge into workable solutions," says Rodney. "What use is a new molecular tool to eliminate a pathogen from trees without an engineer to design a delivery mechanism, or a horticulturalist to advise on solutions that can be integrated in current production systems?"

Dr Laura Fleites highlights the need to understand each element to develop and optimise a system. She explains, "It would be ill-advised to modify one element without being able to predict and measure the effect of the modification on other elements in the system." A collaborative approach ensures that research findings are transformed into actionable strategies that address real-world agricultural issues effectively.

Empowering individuals

A team approach can empower individuals by using diverse expertise and perspectives, allowing each member to contribute unique insights and skills. The recognition and appreciation individuals receive for their contributions promotes a sense of fulfilment and encourages problem-solving from multiple angles, cultivating personal and professional growth. Laura explains, "Individuals working on the project can find their niche and learn aspects of the science that resonate with them. We have team members with varied backgrounds and educational levels, and we solicit feedback from each other regularly. Everyone is encouraged to dig deeper into the subject areas that they find of particular interest."

Empowered individuals make for a more successful team. "Individuals can shine as their effort is appreciated," says Dr James (Jim) Thomson. "I had nothing to do with the original idea to create the Symbiont™ for drug delivery, nor did I come up with the genes that will eventually produce the disease resistance, but I did contribute to the assembly and delivery of those genes for field test, looking for the 'big effect', and I'm proud that I contributed to a potential solution. Everybody, from the farmers that allow us to use their fields (giving up trees that could be used for citrus production) to the people getting on their knees in the mud to test Symbiont™ in the field should all be praised for their efforts." This inclusive approach acknowledges the importance of every individual's contribution, emphasising that success is a result of collaborative effort rather than individual achievements alone. "This project empowers individuals to make meaningful contributions towards addressing complex challenges such as combatting HLB, while also fostering a sense of collective achievement and impact," says Lorenzo. Through collaborative efforts, significant successes have been achieved that would not have been possible otherwise.

Jim highlights the importance of group effort in accomplishing various milestones, including the development of the Symbiont™ concept (see page 8), the expression of disease resistant genes, and the implementation of the inoculation process for field trials. Similarly, Lorenzo emphasises the ground-breaking achievements made in addressing HLB through interdisciplinary collaboration. "By pooling our expertise, we have made significant strides in developing innovative solutions for combatting HLB, such as conducting large-scale field trials with numerous molecules and collaborating with growers across Florida, as well as partners from other states," says Lorenzo.

Changing the way scientists think

The new approach to collaborative and interdisciplinary research is revolutionising the way scientists think about their work and its impact on society and the environment. Traditionally, scientists have been trained to focus on individual research projects aimed at furthering their careers through publications and grants. However, the emergence of existential challenges, like environmental degradation and biodiversity loss, demands a shift towards collective problem-solving. "New scientists need to learn how to balance their personal portfolio of research to contain two types of research: becoming an expert in their field by applying the classic academic model of conducting research and then plugging their knowledge into a collective multi- and transdisciplinary approach to create solutions to existential problems," explains Robert. With the rapid pace of technological advancement leading to a doubling of knowledge approximately every 12 months, scientists must adapt to effectively apply their expertise to real-world problems.

"Scientists often think in terms of self. Not necessary out of selfishness but out of necessity," says Jim. From securing a job to applying for funding, scientists face many day-to-day pressures. A collaborative team approach allows scientists to move beyond the narrow focus of personal achievements and work towards shared goals. This shift in mindset encourages cooperation, knowledge sharing and the recognition of individual contributions within the team. Group publications become a testament to collective efforts, showcasing not only scientific expertise but also the ability to collaborate effectively and prioritise societal needs over personal gain. In fields like agriculture, where challenges like HLB and cherry-X disease threaten livelihoods, the focus must shift from individual efforts to delivering practical solutions to farmers in need.

However, breaking through the traditional mindset of individual achievement has its challenges, often manifesting as 'the wall', where researchers struggle to translate their expertise into tangible solutions. "As researchers analyse their results, they find that they cannot yet use the knowledge gained to deliver a solution to the problem being studied," says Robert. "As a result, they go back and design other experiments still within the boundaries of their area of expertise because they do not know how to advance beyond that limit of knowledge." Overcoming this barrier requires scientists to step out of their comfort zones and engage with diverse disciplines to move their gained knowledge into a deliverable solution. "To me, 'the wall' is the divide between concept and execution," says Laura. "Ideas are great, but they're nothing if you do not advance them in tangible ways. Doing this requires grit and determination."

Dr Tom D'Elia

Biology Professor, Indian River State College, Fort Pierce, Florida

In addition, educators must adapt their training methods to cultivate critical thinking and collaborative skills among future scientists. The next generation of scientists needs to be taught how to navigate the complexities of solution-driven research. "Integrating authentic research experiences and experiential learning into the curriculum has provided a way to develop students' ability to think critically and move beyond traditional methods of memorising scientific concepts," says Dr Tom D'Elia.

There is more to being a scientist than gaining scientific knowledge. "Scientists must be aware of public perception and the regulatory landscape. This is especially relevant for developing novel technology," explains Laura. "This is a huge issue, because even with the best technology in the world, if you don't successfully bring it to market, it's of no value to the consumer."

Embracing diversity for innovative solutions

Diversity plays a crucial role in promoting innovation within the scientific community. By embracing individuals from diverse backgrounds and experiences, researchers can gain fresh perspectives and approaches to problem-solving. In agriculture, for example, growers bring unique insights shaped by practical experience and economic considerations, enriching the research process with their perspectives. "A local grower and citrus consultant, Travis Murphy, took the time to drive us around the citrus groves and show us how growers think about the process of growing citrus," says Robert. "Learning how they took such a practical approach to dealing with all the problems a grower faces, and how they would adapt, created new ways of thinking for our research-oriented minds." Ultimately, the integration of diverse perspectives, collaborative approaches and solution-driven research methodologies holds the key to addressing pressing challenges facing society and the environment.

Developing transdisciplinary teams is essential, bringing together scientists from diverse backgrounds to collaborate closely with different sectors of agriculture. By promoting collaboration between researchers, regulators, healthcare professionals and industry representatives, researchers can develop biosecurity platforms that effectively address emerging threats. "Research and regulatory agencies need to work together to develop platforms with streamlined deregulation processes, and private industry needs to be engaged to support their investment into commercial delivery of these platforms where appropriate," says Robert. "We have all the capabilities to address this issue; we need the will to work together and make it happen."

Symbiont™ *success*

"Innovation realised by bringing together researchers from different disciplines has seen the development of a new way to deliver therapeutics to citrus trees," says Robert. "This is a sustainable and biologically based therapeutic delivery platform called 'Symbiont™' that was developed to provide protection and symptom alleviation to citrus trees from huanglongbing (HLB)." This platform represents an effective approach to addressing HLB, without the need for genetically engineered citrus trees.

At the core of the Symbiont™ platform is the ability to stimulate localised plant cells to form a gall (or growth) on the trunk of citrus trees. Within these galls, termed Symbionts™, engineered citrus cells produce therapeutic molecules such as antimicrobial peptides or plant defence compounds. These molecules are then released into the plant's vascular system, targeting the bacterium responsible for HLB. Importantly, the engineered cells remain localised within the gall and cannot survive if removed from the plant, ensuring environmental safety.

"This platform is based on a method that naturally forms galls on trees that is induced by a commonly occurring bacterium called *Agrobacterium*," explains Robert. "We have demonstrated proof-of-concept of this method in greenhouse grown plants, where HLB-symptomatic potted citrus trees had reduced bacterial titre, reduced HLB, symptoms and more vigorous growth with larger leaves when Symbionts™ expressing antimicrobial peptides were developed on them. We are now conducting research to determine if it can be adapted to commercial citrus production."

Dr Taw Richardson

Chief Executive Officer, AgroSource, Inc.

The achievement of the Symbiont™ platform is down to the solution-drive, collaborative approach the team has embraced. "HLB is a disease that is extremely difficult to manage because it affects every aspect of citrus biology, physiology and production," explains Lorenzo. "The ability to efficiently deliver molecules of interest inside the vascular system of a living tree required a team of individuals able to understand the different aspects of plant biology, chemistry and engineering."

Dr Taw Richardson adds, "Our major success is our current field trial programme for Symbiont™ technology on Florida citrus, taking a completely novel concept to an actual product in the field. This trial represents years of ground-breaking work by dedicated scientists and technicians in the lab and greenhouse and the coordination of researchers at multiple organisations and with extensive communications regulatory agencies to collect supporting data."

The results from this field trial will provide valuable insights into the real-world effectiveness of the Symbiont™ platform in combatting HLB on a larger scale. If successful, this trial could pave the way for widespread adoption of the Symbiont™ platform in commercial citrus orchards, offering a sustainable and environmentally friendly alternative to traditional disease management strategies.

Further applications

The Symbiont™ technology can be used for more than just HLB and cherry X-disease. It can also help fight diseases that affect crops like potatoes and tomatoes grown in fields. These crops are affected by *Liberibacter solanacearum*, a plant pathogen which is transmitted by the potato psyllid and is closely related to the HLB pathogen. Infected plants usually die within four to six weeks of infection, with potato tubers presenting distinct striped patterns and unpleasant taste, making them unsuitable for market. "We are currently using potato and tomato to rapidly screen Symbiont™ constructs for efficacy against *Liberibacter*," explains Rodney. "With some engineering ingenuity to deliver Symbiont™ to field crops, Symbiont™ may provide potato and tomato growers with a highly targeted tool to manage *Liberibacter solanacearum* while reducing insecticide use."

"Although the Symbiont™ platform is currently being developed to control pathogens, this technology may provide some truly novel mechanisms to control persistent insect pests such as codling moth in apples," explains Rodney. "This worm is currently managed using mating disruption, where orchards are flooded with codling moth sex pheromone so that males cannot locate females." However, this method requires pheromone disruptors, which can be laborious, expensive and prone to error. We are excited to initiate research where we develop Symbionts™ that can produce these natural, volatile sex pheromones. "We have already shown that Symbionts™ can produce complex molecules formed by multistep biosynthetic pathways," says Rodney. If successful, this opens the possibility of using Symbiont™ to deliver pheromones directly in orchards, reducing the need for synthetic disruptors and streamlining the mating disruption process. By inoculating pollination trees (or other non-crop plants) with Symbiont™, orchards could be flooded with codling moth sex pheromones more efficiently, offering a promising alternative to traditional mating disruption methods. While further research is required to refine and adapt Symbiont™ for this purpose, it demonstrates the adaptability of this technology beyond its original pathogen control application.

Building momentum

The team's success in developing the Symbiont™ platform has laid the foundation for ongoing research and development efforts. "HLB is a worldwide pathogen that has had a tremendous impact on global citrus production," says Robert. "Success in using our solution-driven approach to address this problem will be a major driver in global research activities for other invasive pest/disease issues." To maintain and build upon this momentum, continued investment in research is essential. This includes refining the platform further, identifying new therapeutic molecules, and conducting field trials to assess efficacy in real-world conditions. Additionally, collaboration and partnerships with academia, industry, government agencies, and growers are vital for knowledge exchange, resource-sharing and collective problem-solving.

Dr Mark Trimmer

President and Founding Partner, DunhamTrimmer LLC

As Dr Mark Trimmer explains, "It is vital we continue to challenge what is working and what is not and avoid committing to one approach. Continuous improvement should be the goal."

Effective communication is also crucial for maintaining visibility, garnering support and attracting funding. By communicating project achievements, milestones and impact to stakeholders, policymakers and the public, the team can amplify its reach and influence. "Finally, remaining adaptable and flexible in response to changing circumstances, new challenges and opportunities is essential," says Lorenzo. "Continuously reassessing strategies, adjusting plans and incorporating lessons learnt ensures resilience and success."

What does the future hold?

International opportunities for collaboration and partnerships hold great potential in addressing diseases such as HLB and enhancing global food security. "Establishing collaborations with international research institutions, universities, and organisations facilitates the exchange of knowledge, resources and expertise," says Lorenzo. "At the same time, seeking funding from international sources such as grants, venture capital and investment partnerships can provide the necessary resources to scale up and commercialise solutions globally." Additionally, capacity building and training initiatives play a crucial role in empowering international stakeholders, including growers, researchers and policymakers. By providing training programmes, workshops and educational materials, stakeholders can enhance their capacity to adopt and implement innovative solutions effectively, thereby contributing to global efforts in ensuring food security.

> **"*It is vital we continue to challenge what is working and what is not and avoid committing to one approach.*"**

Overall, the future is full of excitement and promise. "As we learn to adapt how we conduct science to fit the rate at which we can now obtain and create data and knowledge, we have to adapt how we do science to harness that data and knowledge into deliverable solutions," says Robert. While the path ahead may present various challenges, advancements in technology, research and collaboration offer hope for combatting agricultural diseases sustainably. This collective research effort not only addresses immediate challenges but also holds invaluable lessons for the next generation of scientists. "We hope future scientists learn that they should not avoid uncomfortable situations; uncomfortable is where innovation often lies," says Robert. "Realise that your research can have a greater impact if you recognise it as an important piece of a much bigger puzzle and that you need to find the other pieces that fit with yours."