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Singapore-MIT Alliance for Research and Technology

SMART research reveals promising uses of non-destructive sensors to aid food security and enhance sustainable agriculture

Recent advancements of in vivo and surface or airborne sensors to diagnose plant health will improve crop growth and minimise resources used

- Tracking plant health enables a sustainable way to optimise crop growth, complementing current agricultural techniques
- Non-destructive sensors are crucial for more efficient plant health monitoring, allowing early intervention and augmenting crop productivity
- Current chromatography-based analytical techniques are destructive, highly labour-intensive and time-consuming
- The review with its evaluation of the sensors aims to inspire future development of non-destructive technologies for plant health diagnosis

Singapore, 30 June 2022 – Researchers from the Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP) Interdisciplinary Research Group (IRG) at the Singapore-MIT Alliance for Research and Technology (SMART), MIT's research enterprise in Singapore, and their local collaborators from the Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR) as well as the Department of Chemical and Biomolecular Engineering (ChBE), National University of Singapore (NUS) have published a review that discusses the recent advances in non-destructive plant health monitoring, ranging from electrochemical-based arrays to nanosensors and electronic noses, and why tracking plant health is an attractive and sustainable strategy that can be used to optimise crop growth practices. The review aims to inspire future developments of non-destructive technologies for plant health diagnosis.

To meet the pressing need for global food security and pave the way for sustainable agriculture, the advancement and adoption of agricultural technology are critical in alleviating the conditions of 193 million people in the world who are acutely food insecure. However, sustainable practices need to be implemented to minimise environmental destruction when improving crop yields and productivity. Traditionally, farmers will often only be able to notice signs of their crops' health deteriorating at a stage where reparative measures are limited.

Additionally, the current testing via chromatography-based analytical techniques is destructive as it requires, punching out leaf samples that would cause wounding and tissue breakdown. These methods are also laborious, including lab-based extraction and processing of multiple plant samples for every data point. Thus, scientists have been advancing the field of precision agriculture, developing novel sensors and analytical tools to help farmers guide farm-management decisions. The use of non-destructive or minimally invasive sensors for plant metabolites has emerged as an essential analytical tool for real-time monitoring of plant signalling pathways and plant response to external conditions that indicate overall plant health. These sensors could be incorporated into future farming practices and implemented in high-tech urban farms that use precision, predictive and environmentally controllable farming.

“In light of the increasing demand for food due to the growing global population and concern over food security, developing innovative and sustainable technologies and tools to improve crop yield and quality is timely and essential. Non-destructive plant health monitoring stands as one of the key strategies for improving crop growth practices, complementing current agricultural techniques such as crop rotation, intercropping and genetic modification,” said Dr Gajendra Pratap Singh, Principal Investigator and Senior Scientific Director at DiSTAP.

The team explained their research in the review article titled “Non-destructive Technologies for Plant Health Diagnosis”, published in the prestigious journal *Frontiers in Plant Science.* The findings showed that the sensors could be broadly categorised into those that detect internal (in vivo sensors) and external (plant surface and airborne) signalling molecules.

In vivo sensors are based on either electrochemical sensors or plant nano-bionic sensors. Recent nanotechnology advances have enabled electrochemical and plant nano-bionic sensors to exhibit higher sensitivity and selectivity by utilising unique electrochemical and optical properties. Besides internal signalling molecules, plants also emit signals at the surfaces of their organs as well as through airborne metabolites such as volatile organic compounds (VOCs) for inter-plant communication. Detection of internal and external cues, such as surface and airborne compounds, allows for the non-invasive and real-time diagnosis of plant diseases.

Furthermore, the sensors convert plant signals into digital signals to establish direct communication between plants and growers. “By tapping into plants’ physiological events in real-time, non-destructive sensors enable prompt adjustment of environmental conditions to augment crop productivity while minimising resource use,” added Dr Tedrick Thomas Salim Lew, Scientist at A*STAR’s IMRE and Adjunct Assistant Professor at NUS ChBE, who was the corresponding author of the article.

“The review gave insights into sensors which are versatile and have been successful in extracting spatiotemporal information from a variety of agriculturally important plant species. The sensors will open the possibility of real-time feedback control schemes that can aid in the precise application of fertilisers and plant growth regulators to maximise growth, as well as facilitate timely intervention to minimise yield loss from plant stress,” said Mervin Ang, Research Scientist at DiSTAP and first author of the article.

To address profound challenges in food production in Singapore and the world, DiSTAP has, over the years, introduced novel analytical tools that are rapid, non-destructive and have the ability to detect and provide information from living plants in real-time. This latest review seeks to advance technologies which can be applied to study agriculturally relevant crops in the field, bridging the knowledge gap between model plants commonly used in plant biology and economically important crops.

The review was supported by the National Research Foundation of Singapore under its Campus for Research Excellence And Technological Enterprise (CREATE) programme and the Agency for Science, Technology and Research (A*STAR) Career Development Fund.

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About SMART Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP) [精准农业技术研究中心]

DiSTAP is one of the five Interdisciplinary Research Groups (IRGs) of the Singapore-MIT Alliance for Research and Technology (SMART). The DiSTAP programme addresses deep problems in food production in Singapore and the world by developing a suite of impactful and novel analytical, genetic and biomaterial technologies. The goal is to fundamentally change how plant biosynthetic pathways are discovered, monitored, engineered and ultimately translated to meet the global demand for food and nutrients. Scientists from Massachusetts Institute of Technology (MIT), Temasek Life Sciences Laboratory (TLL), Nanyang Technological University (NTU) and National University of Singapore (NUS) are collaboratively developing new tools for the continuous measurement of important plant metabolites and hormones for novel discovery, deeper understanding and control of plant biosynthetic pathways in ways not yet possible, especially in the context of green leafy vegetables; leveraging these new techniques to engineer plants with highly desirable properties for global food security, including high yield density production, and drought and pathogen resistance, and applying these technologies to improve urban farming.

The DiSTAP IRG at SMART is led by MIT co-lead Principal Investigator Professor Michael Strano and Singapore co-lead Principal Investigator Professor Chua Nam Hai.

For more information, please log on to: http://distap.mit.edu/

About Singapore-MIT Alliance for Research and Technology (SMART) [新加坡-麻省理工学院科研中心]

Singapore-MIT Alliance for Research and Technology (SMART) is MIT's Research Enterprise in Singapore, established by the Massachusetts Institute of Technology (MIT) in partnership with the National Research Foundation of Singapore (NRF) since 2007. SMART is the first entity in the Campus for Research Excellence and Technological Enterprise (CREATE) developed by NRF. SMART serves as an intellectual and innovation hub for research interactions between MIT and Singapore. Cutting-edge research projects in areas of interest to both Singapore and MIT are undertaken at SMART. SMART currently comprises an Innovation Centre and five Interdisciplinary Research Groups (IRGs):

Antimicrobial Resistance (AMR), Critical Analytics for Manufacturing Personalized-Medicine (CAMP), Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP), Future Urban Mobility (FM) and Low Energy Electronic Systems (LEES).

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For more information, please visit: http://smart.mit.edu/

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