**SMART researchers develop new class of plant nanobionic sensor to monitor arsenic levels in soil**

*For the first time, researchers from SMART have engineered a living plant-based sensor for the detection of arsenic in the belowground environment*

- New class of living plant-based sensor interfaces wild-type plants with engineered optical nanosensors, able to detect arsenic levels as low as 0.2 parts per billion
- Arsenic is a heavy metal highly toxic to humans and the ecosystem - inorganic arsenic in rice is estimated by some to lead to 50,000 premature deaths a year
- This novel approach can be used to monitor arsenic uptake in any plant, as well as to convert any non-genetically modified plant to an environmental sensor to monitor soil arsenic levels, enabling applications in agricultural research and environmental monitoring
- Readouts from these new nanosensors can be obtained quickly via portable, inexpensive electronics such as Raspberry Pi-based platforms

**Singapore, 2 December 2020** – Scientists from Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP), an Interdisciplinary Research Group (IRG) at the Singapore-MIT Alliance for Research and Technology (SMART), MIT's research enterprise in Singapore, have engineered a novel type of plant nanobionic optical sensor that can detect and monitor, in real-time, levels of the highly toxic heavy metal arsenic in the belowground environment. This development provides significant advantages over conventional methods used to measure arsenic in the environment and will be important for both environmental monitoring and agricultural applications to safeguard food safety, as arsenic is a contaminant in many common agricultural products such as rice, vegetables, and tea leaves.

This new approach is described in a paper titled, "Plant Nanobionic Sensors for Arsenic Detection", published recently in *Advanced Materials*. The paper was led by Dr Tedrick Thomas Salim Lew, a recent graduate student of the Massachusetts Institute of Technology (MIT) and co-authored by Michael Strano, co-lead principal investigator of DiSTAP and Carbon P. Dubbs Professor at MIT, as well as Minkyung Park and Jianqiao Cui, both Graduate Students at MIT.

Arsenic and its compounds are a serious threat to humans and ecosystems. Long-term exposure to arsenic in humans can cause a wide range of detrimental health effects, including cardiovascular disease such as heart attack, diabetes, birth defects, severe skin lesions, and numerous cancers including those of the skin, bladder, and lung. Elevated levels of arsenic in soil as a result of anthropogenic activities such as mining and smelting is also harmful to plants, inhibiting growth and resulting in substantial crop losses. More troublingly, food crops can absorb arsenic from the soil, leading to contamination of food and produce consumed by humans. Arsenic in belowground environments can also contaminate groundwater and other underground water sources, the long-term consumption of which can cause severe health issues. As such, developing accurate,

effective, and easy-to-deploy arsenic sensors is important to protect both the agriculture industry and wider environmental safety.
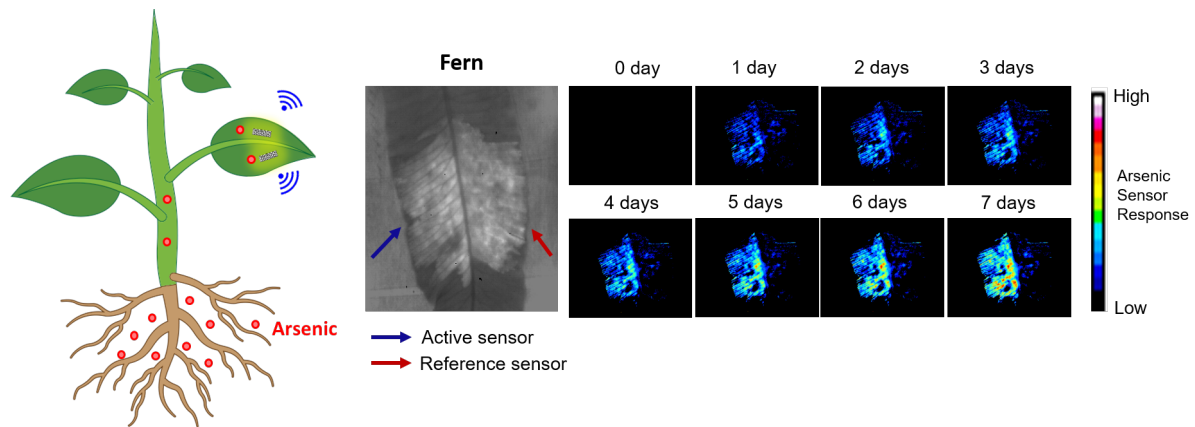


*Non-destructive plant nanobionic sensor embedded within leaves to report arsenic levels within plants to portable electronics, enabling real-time monitoring of arsenic uptake in living plants.*
Photo credit: Dr Tedrick Thomas Salim Lew

These novel optical nanosensors developed by SMART DiSTAP exhibit changes in their fluorescence intensity upon the detection of arsenic. Embedded in plant tissues with no detrimental effects on the plant, these sensors provide a non-destructive way to monitor the internal dynamics of arsenic taken up by plants from the soil. This integration of optical nanosensors within living plants enables the conversion of plants into self-powered detectors of arsenic from their natural environment, marking a significant upgrade from the time- and equipment-intensive arsenic sampling methods of current conventional methods.

Lead author Dr Tedrick Thomas Salim Lew said, "Our plant-based nanosensor is notable not only for being the first of its kind, but also for the significant advantages it confers over conventional methods of measuring arsenic levels in the belowground environment, requiring less time, equipment, and manpower. We envisage that this innovation will eventually see wide use in the agriculture industry and beyond. I am grateful to SMART DiSTAP and Temasek Life Sciences Laboratory (TLL), both of which were instrumental in idea generation, scientific discussion as well as research funding for this work."

Besides detecting arsenic in rice and spinach, the team also used a species of fern, *Pteris cretica*, which can hyperaccumulate arsenic. This species of fern can absorb and tolerate high levels of arsenic with no detrimental effect – engineering an ultrasensitive plant-based arsenic detector, capable of detecting very low concentrations of arsenic, as low as 0.2 parts per billion (ppb). In contrast, the regulatory limit for arsenic detectors is 10 parts per billion. Notably, the novel nanosensors can also be integrated into other species of plants. This is the first successful demonstration of living plant-based sensors for arsenic and represents a groundbreaking advancement which could prove highly useful in both agricultural research (e.g. to monitor arsenic taken up by edible crops for food safety), as well as in general environmental monitoring.

Previously, conventional methods of measuring arsenic levels included regular field sampling, plant tissue digestion, extraction and analysis using mass spectrometry. These methods are time-consuming, require extensive sample treatment, and often involve the use of bulky and expensive instrumentation. SMART DiSTAP's novel method of coupling nanoparticle sensors with plants' natural ability to efficiently extract analytes via the roots and transport them allows for the detection of arsenic uptake in living plants in real-time with portable, inexpensive electronics, such as a portable Raspberry Pi platform equipped with a charge-coupled device (CCD) camera, akin to a smartphone camera.

Co-author, DiSTAP co-lead Principal Investigator, and MIT Professor Michael Strano added, "This is a hugely exciting development, as, for the first time, we have developed a nanobionic sensor that can detect arsenic – a serious environmental contaminant and potential public health threat. With its myriad advantages over older methods of arsenic detection, this novel sensor could be a game-changer, as it is not only more time-efficient but also more accurate and easier to deploy than older methods. It will also help plant scientists in organizations such as TLL to further produce crops that resist uptake of toxic elements. Inspired by TLL's recent efforts to create rice crops which take up less arsenic, this work is a parallel effort to further support SMART DiSTAP's efforts in food security research, constantly innovating and developing new technological capabilities to improve Singapore's food quality and safety."

The research is carried out by SMART and supported by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence And Technological Enterprise (CREATE) programme.

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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 biosynthetic 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, drought and

pathogen resistance and biosynthesis of high-value commercial products; developing tools for producing hydrophobic food components in industry-relevant microbes; developing novel microbial and enzymatic technologies to produce volatile organic compounds that can protect and/or promote growth of leafy vegetables; 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 six Interdisciplinary Research Groups (IRGs): Antimicrobial Resistance (AMR), BioSystems and Micromechanics (BioSyM), Critical Analytics for Manufacturing Personalized-Medicine (CAMP), Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP), Future Urban Mobility (FM) and Low Energy Electronic Systems (LEES). SMART research is funded by the National Research Foundation Singapore under the CREATE programme.

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


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