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Singapore elevates precision farming with innovative plant e-skin coupled with digital-twin monitoring system

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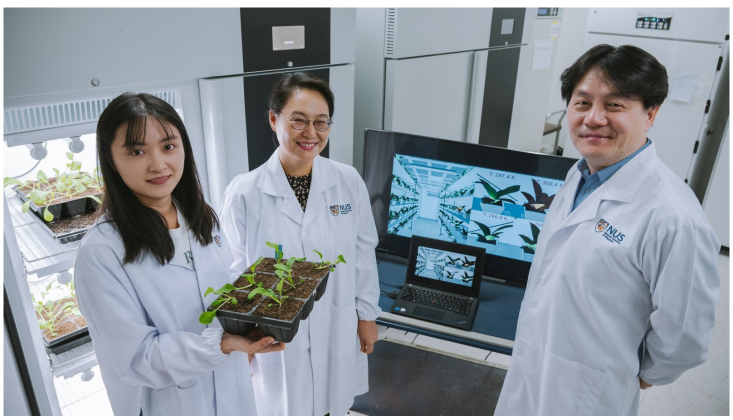

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Precision farming is an emerging field that uses analysis tools like sensors to collect data on crop plant conditions, such as temperature, humidity, moisture, and nutrient levels. The data collected from these sensors can help to optimise crop yield and allow farmers to promptly respond to changes in plant environments like heat and increased rainfall.

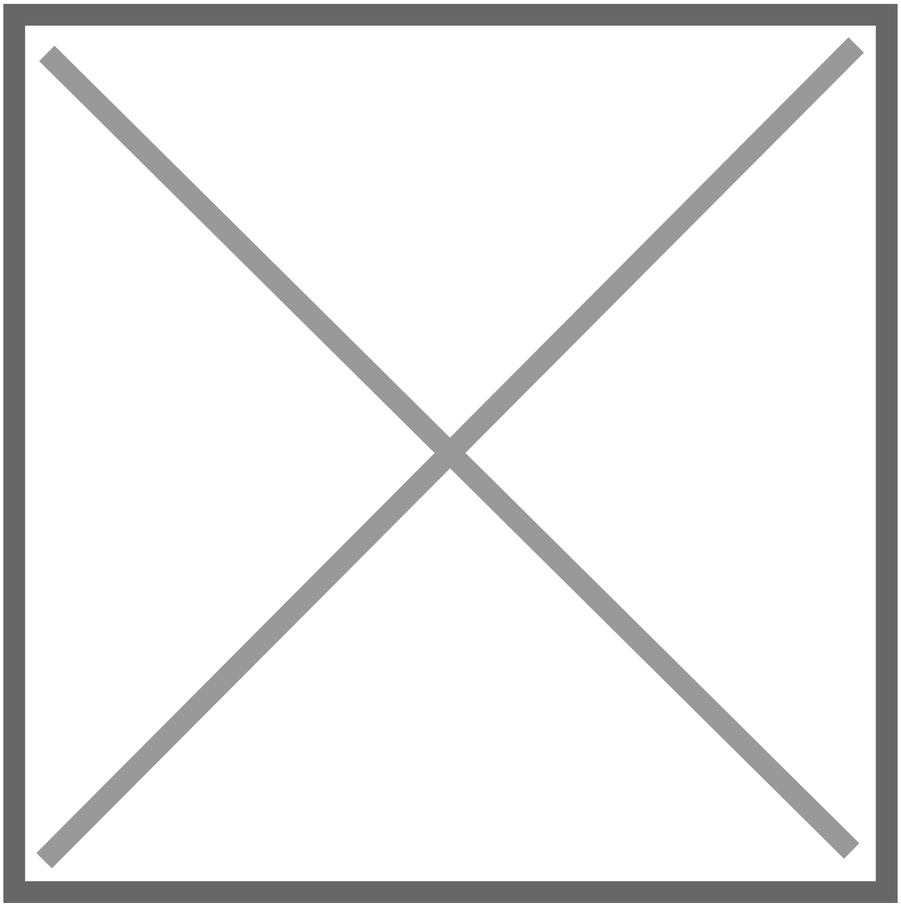
Advancing plant sensor technologies is a multidisciplinary team of researchers from NUS that has created a first-of-its-kind all-organic plant e-skin for continuous and non-invasive plant monitoring. Complementing this innovation, the team also developed a digital-twin plant monitoring system to translate the data collected from the plant e-skin into a visualisation of the plantâ??s physical characteristics in real-time, paving the way for efficient decision-making in crop breeding and precision farming.

Innovative e-skin for plant monitoring

Commercially available plant sensors are often rigid, heavy and opaque, which may cause damage to the plants and affect plant growth when mounted onto the plants. Current devices are also unable to provide customised, continuous and accurate data about the plantâ??s physical conditions.

To resolve these limitations, the NUS research team designed the innovative plant e-skin to be biocompatible, transparent and stretchable using commercially available organic materials. The ultrathin plant e-skin has a thickness of 4.5 micrometres, which is about 10 times thinner than the diameter of a strand of human hair which is around 50 micrometres. The e-skin comprises an electrically conductive layer, sandwiched between two transparent substrate layers. The incorporation of these layers renders the plant e-skin remarkably transparent, allowing over 85 per cent of light to pass through within the wavelength range of 400 to 700 nanometres, perfectly aligning with the light absorbance wavelength needed for plants to produce energy.

The team demonstrated that the plant e-skin could perform reliably on leaves exposed to stress conditions, such as heat and lack of water. The versatile plant e-skin is also compatible for different types of plant leaves and various plant growth environments like rainfall. Different types of sensors â?? for measuring strain and temperature â?? are patterned on the e-skin using simple lithography. The e-skin is then placed on the surface of plant leaves to perform the monitoring of key parameters.



When designing the strain sensor, the researchers took into consideration the requirements needed to monitor the growth of small and delicate leaves while protecting the plant. Using their novel plant e-skin, the NUS team successfully monitored the growth pattern of Field Mustard leaves, showing how the sensor can conform to the surface of the leaf for accurate monitoring, and seamlessly integrated onto plant leaves without causing any observable adverse damage. In addition, the e-skin temperature sensor enables reliable and non-invasive monitoring of the surface temperature of plant leaves.

â??The ability to measure leaf surface temperature is a unique feature of our plant e-skin that is currently not found in conventional temperature sensors. This feature allows us to collect data to understand how to mitigate heat stress on leaves caused by long-term exposure to heat, making it beneficial for precision farming of economically valuable crops,â?? said Assoc Prof Lee.

Digital-twin system for precision farming: To complement the plant e-skin, the NUS research team developed a digital-twin plant monitoring system to visualise the plant surface environment in real time, providing an intuitive and vivid platform for plant monitoring.

Data collected from the sensors on the plant e-skin is processed to generate a digital output, which is used to create a digital-twin of the plant that mirrors the physical conditions of the real plant. Using temperature as a test condition, the NUS team demonstrated that the digital-twin system can instantly translate temperature fluctuations on the plantâ??s leaf surface into colour changes on the plantâ??s digital-twin, for users to visualise the changes in plant surface temperature.

In the next phase of their work, the NUS researchers hope to integrate more functions into the plant e-skin, such as a humidity sensor and chemical sensor, and couple them with the digital-twin plant system to enable a more comprehensive monitoring of the plantâ??s physical characteristics.