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New insights into sustainable tomato production

Collaboration between the Australian Plant Phenomics Network (APPN) and the ARC Research Hub for Protected Cropping (PC Hub) is delivering new insights into sustainable tomato production. Using advanced plant phenotyping, this research demonstrates how smarter nutrient management can improve productivity while reducing resource use.

Recognising the importance of tomato production within Australia's protected cropping sector, this research used APPN infrastructure and advanced phenotyping technologies to help improve greenhouse tomato cultivation through optimised growth substrate selection and nutrient management.

Funded by the La Trobe Institute for Sustainable Agriculture and Food (LISAF) and the ARC Research Hub for Protected Cropping (PC Hub), the work undertaken so far has highlighted how reduced fertiliser usage can lead to a range of improved production metrics, while generating high-quality imaging datasets to support future AI-driven crop monitoring.

In a collaboration with colleagues from the ARC Centre of Excellence in Plants for Space, data collected from APPN's environmental sensors and mechanical controls were also used to assess the energy footprint of individual inputs in hi-tech greenhouses.

Growing crops using protected cropping systems like greenhouses or vertical farming systems means food can be grown where it normally wouldn't be able to, helping to safeguard the year-round availability of fresh produce.

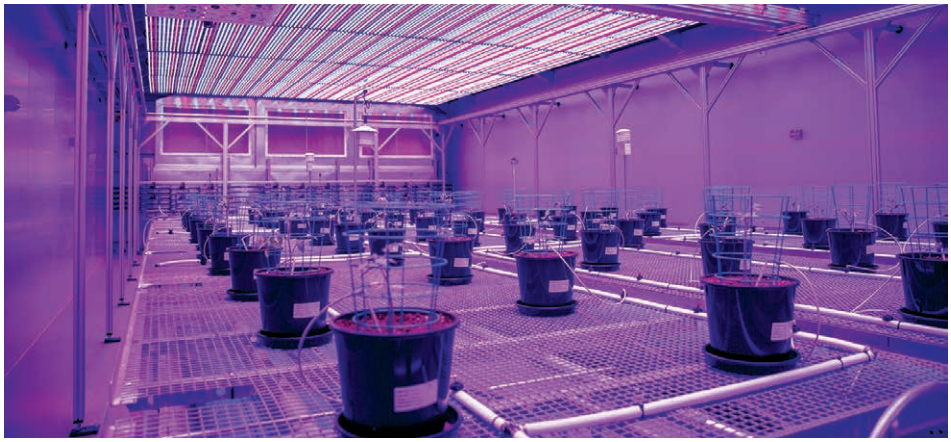
A variety of crops are grown this way in Australia, including tomatoes, cucumbers, capsicum, herbs, leafy salad vegetables and berries. Tomatoes are an important vegetable crop for Australia's horticultural sector, having the third highest farm-gate value and second highest production volume in 2023-24. Over a quarter of this production is grown in protected cropping systems, with cherry and grape varieties predominating.

However, protected cropping is not without its challenges, including high energy and resource use, labour costs, pest and disease risks, and waste management requirements. This research is part of a broader program aimed at addressing some of these challenges that lie ahead.

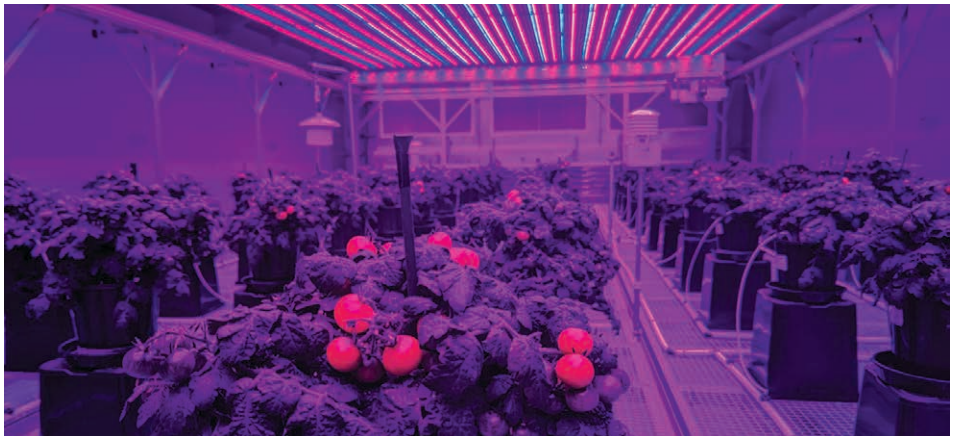
Tomatoes can be grown in a variety of ways within protected cropping systems. However, different traits may be prioritised depending on how the tomato plant is being grown. In vertical farming, growers prioritise compact plant growth, faster flowering and fruit ripening, and a high harvest index (the proportion of harvested fruit relative to total biomass).

This contrasts with more conventional greenhouse cultivation, where vine tomatoes are typically grown for six to 12 months under continual pruning and rigorous pest and disease management. However, nutrition practices tend to follow a one size fits all approach in different systems, despite evidence showing variety specific nutrient pathways having a strong influence on plant growth and development.

Therefore, customised fertigation practices are needed to reach yield and quality targets in specific production systems. As such, understanding nutrient requirements for 'Micro-Tom' is a key focus of this research. 'Micro-Tom' is a dwarf cherry tomato variety



Set up of the project experimental design at the glasshouse facility.



Above and left: 'Micro-Tom' cherry tomato plants used as a model crop to demonstrate controlled-environment growth under supplemental LED lighting in the glasshouse.

well suited to high density greenhouse production or vertical farming systems but is commonly used as a model organism in tomato research.

To further enhance production efficiency in protected cropping systems, advanced technologies such as automated environmental controls, remote sensing, and AI-driven analytics can also be leveraged to create smart farming tools that monitor plant health, model crop performance and predict yields.

A key example of this is the use of imaging technologies to monitor and model crop performance. Two popular imaging technologies with strong agricultural applications – RGB and hyperspectral sensing – use reflected light to generate information about a plant's morphological characteristics, or its physiological or biochemical/metabolic status. However, developing these types of tools requires vast amounts of high-quality data from environments similar to those used in protected cropping – a function that can be achieved with high precision in APPN La Trobe's greenhouses and controlled environmental facilities.

Outcomes

Work so far has revealed that reducing nitrogen supply from an industry standard in 'Micro-Tom', can improve harvest index and nitrogen use efficiency, with minimal impact on yield – supporting the idea that a variety's genetic makeup can influence responses to different fertigation strategies.

Changes to harvest index and nitrogen use efficiency suggest that the plants became better at allocating their resources towards fruit rather than vegetative growth – reducing leafy biomass, which in turn reduced water use, and associated green waste.

Another key finding was that lower nitrogen use combined with a more airy, porous growth substrate resulted in shorter production cycles and more synchronized fruit ripening – this can provide greater operational flexibility by lowering the risk of pest and disease outbreaks and reducing manual workloads in the greenhouse.

These findings will be applied to optimise performance of commercially relevant tomato varieties as part of future trials. In the work completed to date, manually measured crop performance metrics have been used to identify superior fertigation regimes for 'Micro-Tom'.

In future research, these manual measurements will be integrated with spectral indices derived from the experiment's RGB, and hyperspectral sensing efforts to develop predictive models that detect similar crop performance traits (for example, improved nitrogen-use efficiency) for specific tomato varieties and cultivation conditions.

Multivariate stress studies – combining multiple abiotic – and potentially biotic – stressors are also planned to generate more robust training data for identifying spectral signatures specific to each individual stress. Ultimately, AI-assisted interpretation of spectral data from RGB and hyperspectral imaging will support the generation of digital indicators that inform growers about plant health, nutrient status, and expected yield.

Energy and plant productivity data is important for carrying out life cycle assessments (LCA) of greenhouses and other controlled environment facilities – structures that can share many similarities with those used in space farming.

"...REDUCED FERTILISER USAGE CAN LEAD TO A RANGE OF IMPROVED PRODUCTION METRICS..."

To support this, the high-tech plant growth facility at APPN, La Trobe has also delivered pilot-scale data on the energy use of environmental control units (temperature, humidity, fertigation and lighting) for tomato crops, as tomatoes could be one way people are fed in space.

Researchers from the ARC Centre of Excellence in Plants for Space will be able to use this data to better understand energy requirements for tomato production for space farming.

Impact

Efforts so far have established a strong foundation for future research aimed at optimising greenhouse tomato production. While long-term impacts will emerge as part of the broader program, APPN has helped validate practices that are expected to offer a range of tangible benefits for the industry. Improving production workflows based on plant phenotyping data has the potential to deliver important economic and environmental impacts for the protected cropping sector.

Plants showing results of high nitrogen (top) and low nitrogen (above).

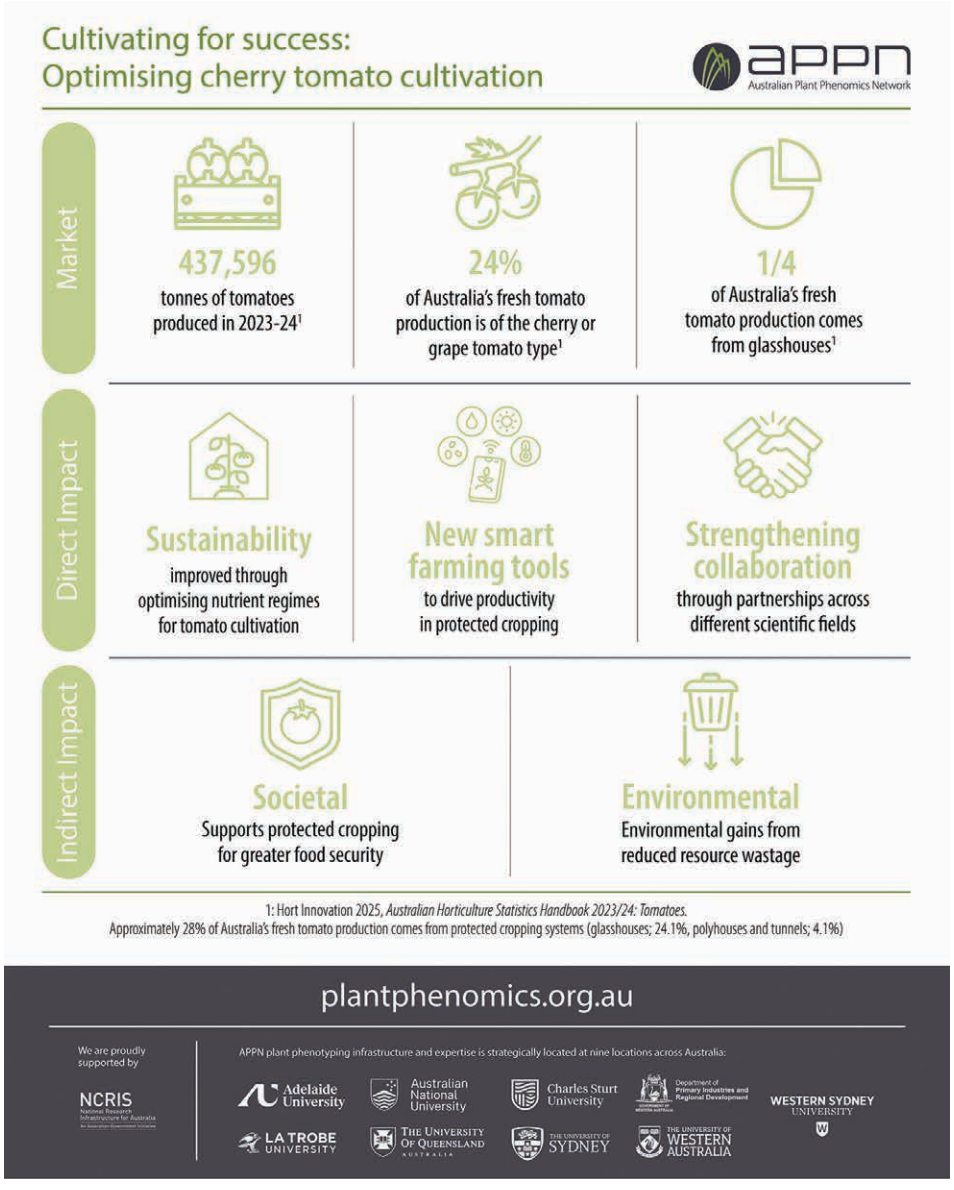
'Micro-Tom' harvest in the glasshouse.

Working together

This study brought together experts in horticulture, plant nutrition, molecular plant physiology, engineering and phenotyping from La Trobe University.

Newly formed collaborations that include the ARC Industrial Transformation Research Hub for Protected Cropping and the ARC Centre of Excellence in Plants for Space are set to strengthen future research initiatives and deliver impactful, industry-driven outcomes. The greenhouse and controlled environment facilities at APPN La Trobe were central to the project. Automated fertigation systems in both spaces enabled precise nutrient treatments.

Similarly, precisely controlled lighting included sunlight supplemented with cool-white LEDs in the greenhouse and a specific combination of red/ blue LED lighting in the controlled environment room. APPN's expertise and non-destructive imaging technologies – including RGB, hyperspectral VNIR, fluorescence, and thermal sensors were also vital for capturing the data required for model development.



Future impacts of the research may include:

1. Enhancing the long-term sustainability of production. Streamlining operational processes, and minimising outputs like green waste while still achieving yield and quality targets can enhance the long-term sustainability of production. Reducing energy, irrigation and fertiliser inputs are also cost reduction measures. Both elements help to ensure that high tech protected cropping systems are sustainable and profitable, supporting Australia's ability to protect food security into the future.

2. Developing smart farming tools that boost production efficiency. Developing innovative, non-invasive imaging techniques and data for AI-driven plant health and yield prediction models will support efficiency improvements. Increased efficiency will reduce the time and labour limitations of manual plant assessment, while enabling faster decision-making in response to a range of plant stressors.

3. Strong collaborations to support impactful research. Fostering interdisciplinary research can enable more effective resource sharing, accelerating and creating opportunities for problem solving and innovation. While this project focused on tomato production, the technology, techniques and data that was shared could have long term implications for crop cultivation in extreme environments.

Coming up...

Want to learn more? This research will be featured in an upcoming Protected Cropping Australia X PC Hub podcast, where our researchers will discuss the findings, their practical implications for growers, and the role of advanced plant phenotyping in the future of protected cropping.
PCA members, see your email in October for more details!

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Acknowledgements

This article has been republished in full with permission from APPN. It originally appeared on the APPN website.

The Australian Plant Phenomics Network (APPN) is a distributed network of national research infrastructure platforms offering open access to state-of-the-art plant phenomics technologies, tools and expertise, used by academic and commercial scientists. APPN is enabled by the National Collaborative Research Infrastructure Strategy (NCRIS).

This project was undertaken at the La Trobe University Node of the Australian Plant Phenomics Network.

The ARC Research Hub for Protected Cropping (PC Hub) is driving a transformation in Australia's horticultural and medicinal agriculture industries by advancing protected cropping (PC) and improving sustainability, crop quality, yield, and reliability.

The PC Hub is part of the La Trobe Institute for Sustainable Agriculture and Food (LISAF), a world-leading research and training Institute delivering innovative solutions for sustainable and nutritious food production in a resource and climate-constrained world.

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