Bacterial Plant Diseases Programme

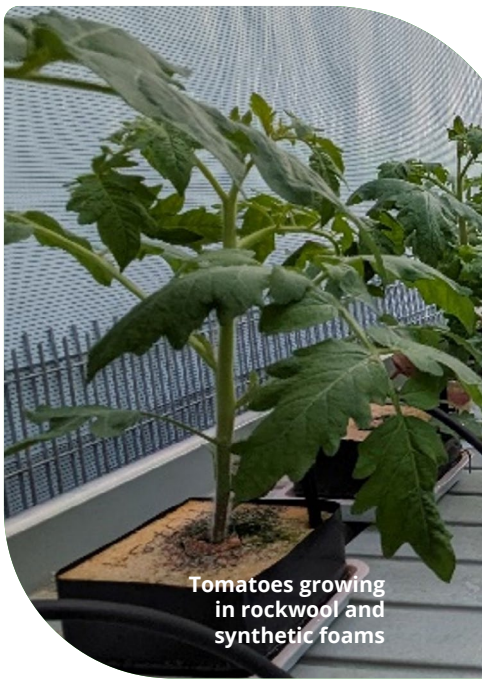
Commercially growing hydroponic tomatoes

OPTIMISING GROWTH SUBSTRATES AND HARNESSING SOIL MICROBIOMES TO REDUCE DISEASE IN HYDROPONICALLY GROWN TOMATOES

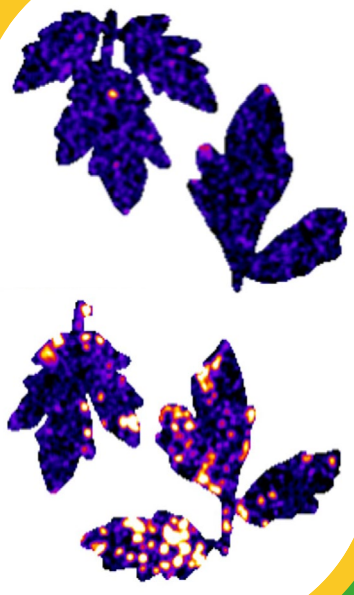
Conventional hydroponics makes plants particularly vulnerable to disease

Expanding soft fruit production, including tomatoes (*Solanum lycopersicum*), in protected environments, like glasshouses, is essential given increasing pressures on agricultural soils. However, plants grown in conventional hydroponic systems, often in rockwool, are particularly vulnerable to disease. Crops evolved growing in soil where they develop a protective microbiome of bacteria and fungi. This microbiome can directly kill pathogens, outcompete them and enhance the plant immune system.

Some soils have a microbiome that is particularly good at preventing plant disease and are termed 'disease suppressive soils'. In contrast, rockwool appears to be a poor substrate for supporting beneficial microbes. If the microbiome of these disease suppressive soils could be characterised and reproduced in hydroponic systems with novel, optimised growth substrates it could help prevent disease and improve yields.



Tomatoes growing in rockwool and synthetic foams



Bioluminescent pathogenic *P. syringae* bacteria on leaves of tomatoes grown in disease suppressive soil (top) and disease conducive soil (bottom)

This research manipulated the hydroponic microbiome and developed new growth substrates

To identify a disease suppressive soil, we grew tomatoes in a variety of soils from long-term agroecology trial plots. These tomato plants were then infected with genetically-modified bioluminescent (light-emitting) *Pseudomonas syringae* which causes bacterial speck disease. The bioluminescence meant pathogen growth could be quantified and the soil with the least disease identified.

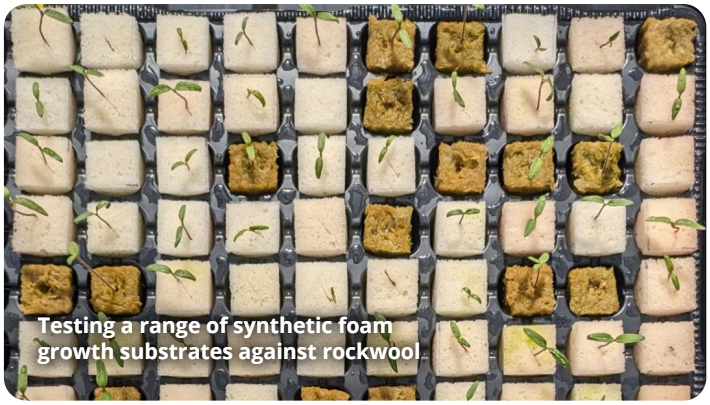
Using this soil, we developed methods to extract the microbiome and created an inoculum to apply to hydroponically grown tomatoes. High throughput DNA sequencing was used to determine which of the microbes we applied could survive and grow on tomatoes in hydroponic systems.

New polyurethane foam growth substrates were also developed. These foams were tested and compared to rockwool to determine which physical properties improve plant growth and support beneficial microbes.

Discoveries

We established that microbiomes from soil can alter the hydroponic microbiome and that polyurethane foams can outperform rockwool.

- We identified a disease suppressive soil that reduced disease in tomato, but had little detrimental impact on plant growth (a common problem with disease suppressive soils).
- We produced a disease-suppressive soil extract that appeared to contain the majority of bacterial and fungal varieties and was easy to apply to hydroponically grown plants.
- Applying our soil-derived inoculum to hydroponically grown plants altered the microbiome, making it more diverse and much more similar to soil.
- We developed polyurethane foam growth substrates which out-performed rockwool, in terms of the germination rate and shoot mass of tomatoes planted in them, and could be manipulated for specific properties relevant to plant/microbial growth.
- We developed free and open-source photo-based methods for high-throughput monitoring of tomatoes, for use in growth trials and plant health monitoring without prohibitively expensive equipment or software.



Testing a range of synthetic foam growth substrates against rockwool

Phenotyping tomatoes using photography

Recommendations

Our research has shown that there is potential to improve hydroponic systems by engineering the microbiome and optimising the growth substrate, but more research is needed.

- Further research to understand whether the disease suppressive soil extract reduces pathogen abundance and protects plants from disease.
- Assess and optimise our newly developed synthetic foams for both tomato growth and colonisation by beneficial microbes.
- Increased collaboration with growers to optimise and evaluate synthetic soils and microbiome application in commercial horticulture.
- Encourage wider use of our open-source methods for monitoring tomato growth.

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This document is based on this and other research:
Wright, H.C., Cameron, D.D. and Ryan, A.J. (2022) Rational design of a polyurethane foam. Polymers. 14 (23). 5111. ISSN 2073-4360

Wright, H.C., Lawrence, F.A, Ryan, A.J and Cameron, D.D. (2023) Free and open-source software for object detection, size, and colour determination for use in plant phenotyping. Plant Methods. 19, 126)

Bacterial Plant Diseases Programme

An interdisciplinary research consortium working together to understand bacterial plant diseases to protect UK farms, forests and gardens.

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