Environmental monitoring within greenhouse crops using wireless sensors

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1 Introduction

Because variables such as temperature and humidity have a profound effect on the activity of crop pests, diseases and natural enemies, the ability to monitor environmental conditions within a crop has always been important for crop protection.

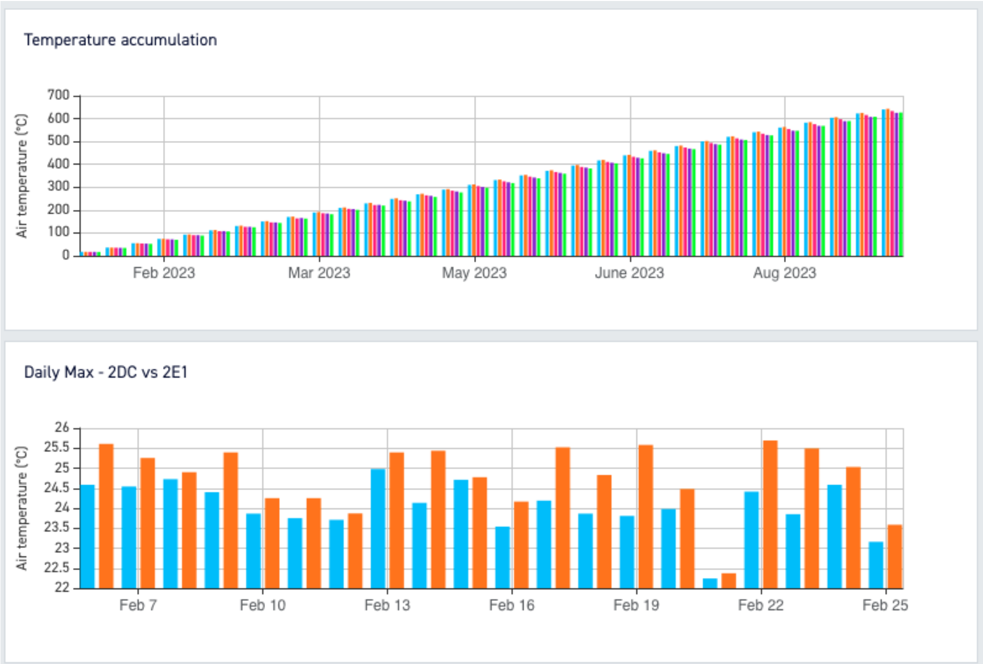
2 Measuring environmental conditions in greenhouses

In greenhouse crops, the standard method for many years has been to use data from the climate management system, often using a very small number of fixed environmental sensors in central positions that feed data directly to a locally hosted system. However, environmental conditions can vary significantly within the glasshouse in terms of horizontal (floor) location, crop height (clearly important for vine crops such as tomato, pepper and cucumber) and with time. Such variation affects pest and diseases – for example it can lead to P&D 'hotspots', or locations where biocontrols work better / worse than in others. Crop protection tools such as biological controls, biopesticides, and pest / disease forecasting – all of which are very sensitive to environmental conditions at localised scales – are taking on greater prominence in Integrated Pest and Disease Management systems, which means that the need for 'granular' (fine scale) accurate and reliable environmental data is becoming more critical.

3 Sensors to capture data at multiple locations

The way forward is to incorporate remote IoT sensors that capture data at multiple locations. This can be done using wireless (networked) sensors that send data to a server for analysis, and with data being accessed via a cloud-based system, and visualised using a dashboard that interprets and presents the environmental data matched to the grower's needs. Networked sensor systems can provide alerts when environmental conditions in one part of the greenhouse put the crop there at risk from outbreaks of powdery mildew, tell the grower when conditions are optimum for application of a particular biocontrol agent, or when changes in conditions mean that a pest is at risk or outstripping the ability of its predators to control it (as happens with spider mites, for example). Such a system offers many advantages. The use of cloud-based data analysis enables complex algorithms to be developed, deployed and regularly updated, for example epidemiological models for pests and diseases based on machine learning from big data sets. There are options to deploy multiple sensors in a static array throughout the greenhouse, to use mobile sensors on scissor lifts or autonomous vehicles, or a combination of both. Wireless sensors are quick to put in the crop and have potential for simple 'plug and play' deployment. Making the whole system wireless enables the grower / agronomist to access data anywhere using a smartphone or tablet. The results can also be presented through a dashboard tailored to the particular needs of a grower or a crop type, giving data summaries, analytics, and alerts – leading to faster, better decision making.

4 SmartProtect case study

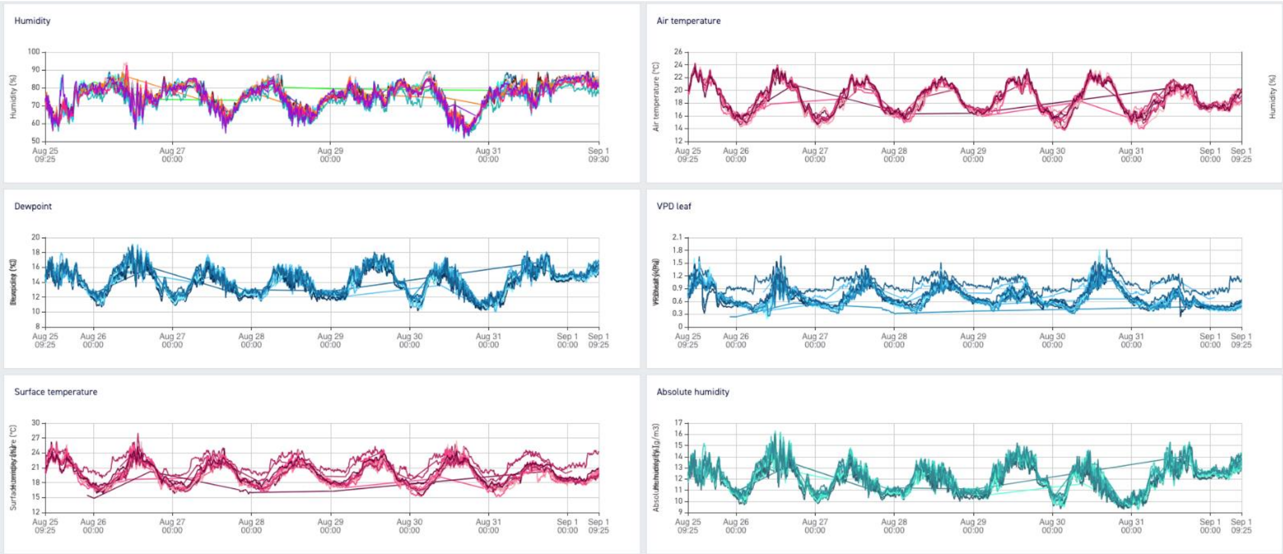


As part of SmartProtect, we have been testing out a wireless environmental sensor system in a commercial high-wire tomato crop. The system was kindly hosted by R&L Holt, who are the largest tomato grower in the UK Midlands. R&L Holt operate from four nurseries with a total coverage of 17 ha of state-of-the-art glasshouses that includes all year-round production. They focus on producing modern, small fruiting cultivars sold to UK supermarkets. Their crop protection is based on a comprehensive Integrated Pest and Disease Management strategy with a large investment in biological control. Production is reliant on biological pollination with commercially managed bumblebees, and this is combined with the IPDM system to ensure that any crop protection interventions used do not impact negatively on pollination.

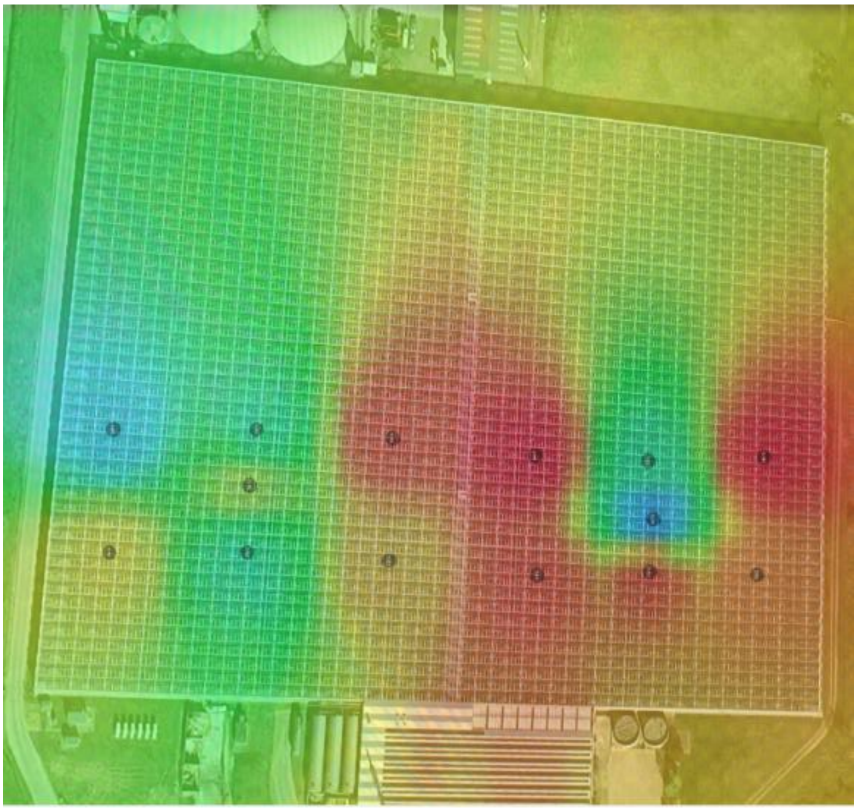
The work was done in a conventional seasonal (March – December) crop in a 5-ha glasshouse. The house has a central concrete path and the crop rows are c. 100 m long running from each side of this. The sensors that we tested were part of the ZENSIE platform from 30MHz, who are based in the Netherlands, and they were set up and managed by Fargro Ltd., a UK horticulture company with expertise in digital agronomy. There are other sensor systems on the market. We are not advocating the use of any one system over others; rather, our aim here was to investigate and demonstrate how a wireless sensor network can be used in commercial horticulture. The dense foliage and the height of high-wire tomato crops can potentially impede the wireless signal, and hence the work here provided a very good test of the system.

We used 14 microclimate sensors, deployed across the width of the glasshouse. We set up two rows of six sensors per row (n = 12) plus two extra sensors placed in between the two rows of six. Each sensor measured leaf temperature, and temperature humidity. Data were sent wirelessly to a gateway (ethernet network connection) that was housed in the nursery office. Repeaters were placed between the sensors and the gateway that boosted the signal, which may be needed to permit data transfer throughout the glasshouse.

The data were visualised through a range of widgets on the dashboard: in our case, widgets were set up for humidity (both percent humidity and absolute humidity), air temperature, surface temperature, dewpoint, and VPD. These data were shown as real time (actual) readings, but Fargro also set up widgets to show the accumulated air temperature and growing degree hours, alongside two temperature-based insect widgets, for *Macrolophus* and *Tuta absoluta*: these act as alerts to warn users when temperatures reach the activity thresholds for these pests.



An additional feature was to overlay the air temperature data on a satellite image of the glasshouse, so that changes in temperature over time and space could be viewed as a heatmap. This showed clearly that there was temperature variation along the crop row; in February, for example, a 1.5°C difference in temperature was observed at midday along the row. It was also useful in demonstrating how the pattern of temperature hotspots varied along and across the rows during the day, reflecting the movement of the sun and changes in cloud cover.



The sensors also indicated variation in VPD of up to 0.8 kPa on occasions at different points in the glasshouse, which could affect plant growth and nutrient uptake, both of which could impact on crop protection.

5 Remaining challenges

The Zensie platform is a proven system, and we could see obvious benefits for having real time data available across the whole of the glasshouse. Linking the microclimate data to models on the biology of the crop, pests and diseases, and beneficial organisms (biocontrols and pollinators) has real potential to better inform crop protection decisions and help maximise production. There are a number of challenges remaining with wireless sensors, although all are solvable with time. At the moment, the prices of these innovative technologies are relatively high, which is a deterrent for early adopters (the so called 'early adopter tax'). We don't yet know whether it is better to use multiple sensors in a fixed array in the crop (which has high unit costs but may give better data quality) or a single sensor mounted on a vehicle (low unit cost but at the possible expense of lower data quality). There is also going to be a trade off between data quality, reliability and robustness versus price. There are also some outstanding questions about the best ways to transmit data from sensors to the cloud, while more work needs to be done to develop decision support models linked to sensor data. However, there is rapid development within the industry and demand will be pushed by ongoing issues around labour, energy prices, and access to agronomists and crop protection consultants.

6 Long term vision

The long term 'vision' is that eventually we should see integrated, semi-autonomous crop protection systems based around wireless sensing, analytics, and robotics. Pest and disease detection systems would be combined with environmental sensors, with the data inputted into IPM models that predict where a pest / disease outbreak is occurring, the rate of its development based on environmental conditions, and making recommendations on the best course of action using knowledge on the activity of any pre-existing controls (e.g. preventative biocontrols) and the efficacy of curative controls (biopesticides or IPM-compatible chemical pesticides). Treatments would then be applied at the right place, time and dose using autonomous vehicles with robotic, low volume sprayers or other application technologies. Growers may want to cherry pick parts of a system depending on their business needs. For example, it might be that just using manual pest scouting with a GPS enabled tablet is sufficient in one case, whereas in other cases the grower might benefit from a fully automated system linking scouting robots, cloud-based decision support and robot sprayers. It's likely that the effectiveness of these systems will increase over time, while the price will come down.

7 Acknowledgements

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For more information about Smart systems for use in greenhouse production watch this webinar:

https://www.youtube.com/watch?v=boVdr_J6XgQ&feature=youtu.be