Remote Visual Monitoring System for Tunnel Grown Crops †

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Abstract: With soft fruit growers facing tighter margins due to changing economic circumstances and competition from low-cost imports, it is imperative that growers can maximize their yield whilst maintaining a healthy crop. With longer growing seasons, disease can be a real problem affecting the health of the plant whilst also limiting the potential yield further impacting the grower. This project aims to provide a tool for the grower to remotely monitor a crop from anywhere with access to the internet. Using clusters of custom designed modules consisting of low-cost computing and imaging equipment, a system has been developed to monitor a crop throughout a growing season remotely. The system was able to power itself via renewable energy while capturing images of strawberry plants, inoculated with *Phytophthora cactorum*, via a fully customizable schedule for data collection, which reduced the risk of pathogen contamination of other crops by removing the requirement to physically visit the crop. The self-powered remote monitoring system is scalable by adding or removing clusters and lends itself to the collection of additional sensory data also.

Keywords: Digital Agriculture; Raspberry Pi; Data Collection; 3D Printing;

Materials and Methods

- Site assessment for suitable coverage
- Power requirements – Generation & Storage
- Image capture & data storage
- Data connectivity

Figure 1. A view down the length of the tunnel used for data capture.

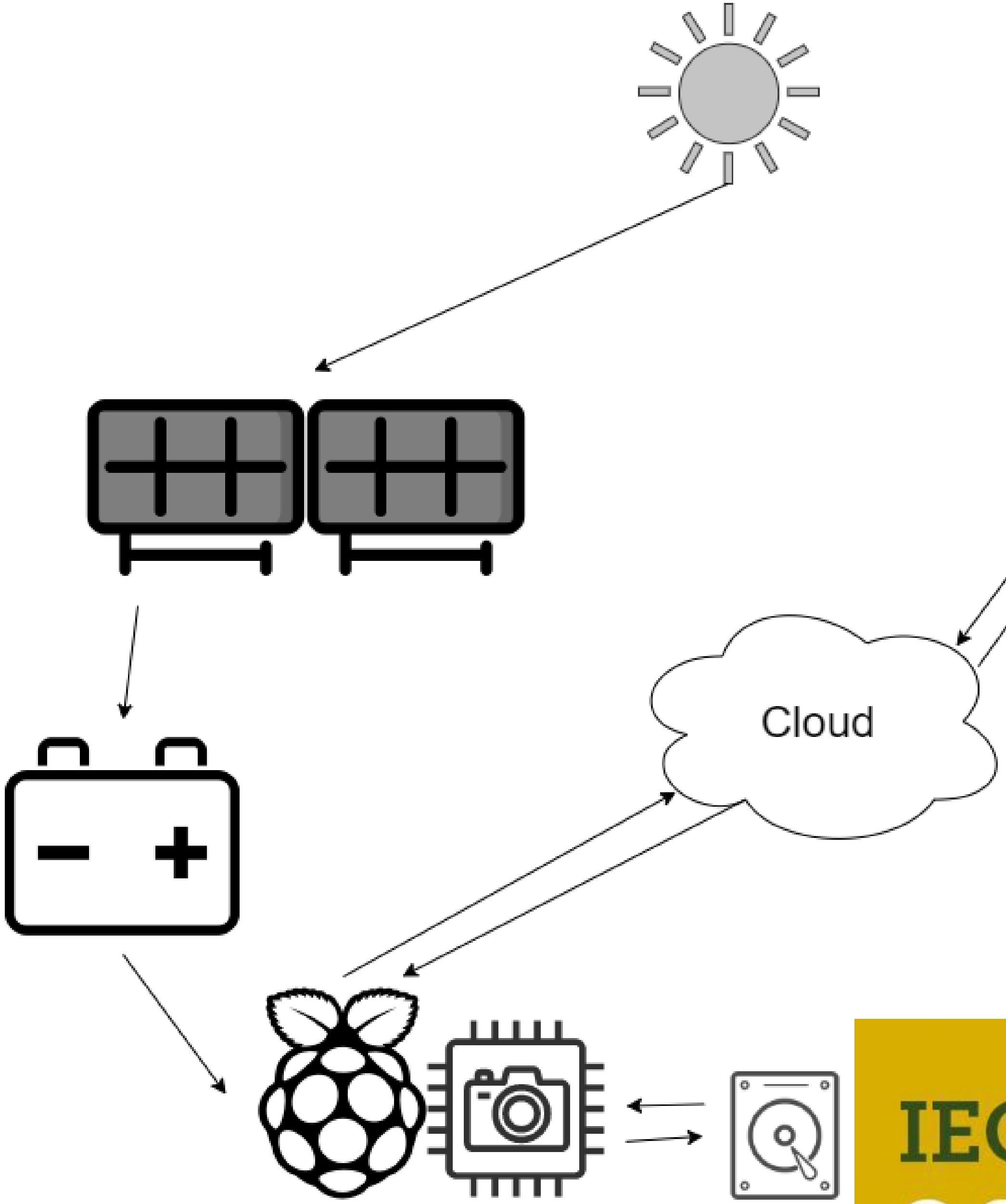

Figure 2. Simplified overview of the system setup.

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Tunnel in this case was a 70m long, 8m wide tunnel, that was ~4.5m high at the highest point. There were limitations with regards to capture module fixing points (figure 3).

Crop was grown in bags on upturned trays laid along the tunnel length. Only one side was required for data capture.

Figure 3. Limited fixing points for capture modules.

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As the period for data capture was over the summer, the power of the sun was harnessed to provide electricity.

Two 150W monocrystalline photovoltaic panels were placed facing due south to maximize efficiency (figure 4a).

For the power storage two 110Ah lead acid batteries were used see (figure 4b).

Figure 4. a, Top-left – siting of the two 150W solar panels facing due south,
b, Bottom-right – two 110Ah lead acid batteries used to supply modules with power

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Images were captured periodically via custom 3d printed modules (figure 5a,b and c) that contained an 8-megapixel sensor controlled via either a Raspberry Pi 3B or a Raspberry Pi Zero, modules were attached to the top rail in the growing tunnel.

Modules were clustered together with two Pi Zero's connected via USB to a central Pi 3B, which supplied power to the more compact Pi Zero's.

Images (figure 5d) once captured were transferred to a network attached 500GB SSD.

Figure 5. a, Top-left – 3d printed case for capture module; b, Top-right – RPi Zero capture modules fitted inside custom casing; c, Bottom-left – how the capture modules can connect to the top rail; d, Example of an image captured from the top of the tunnel.

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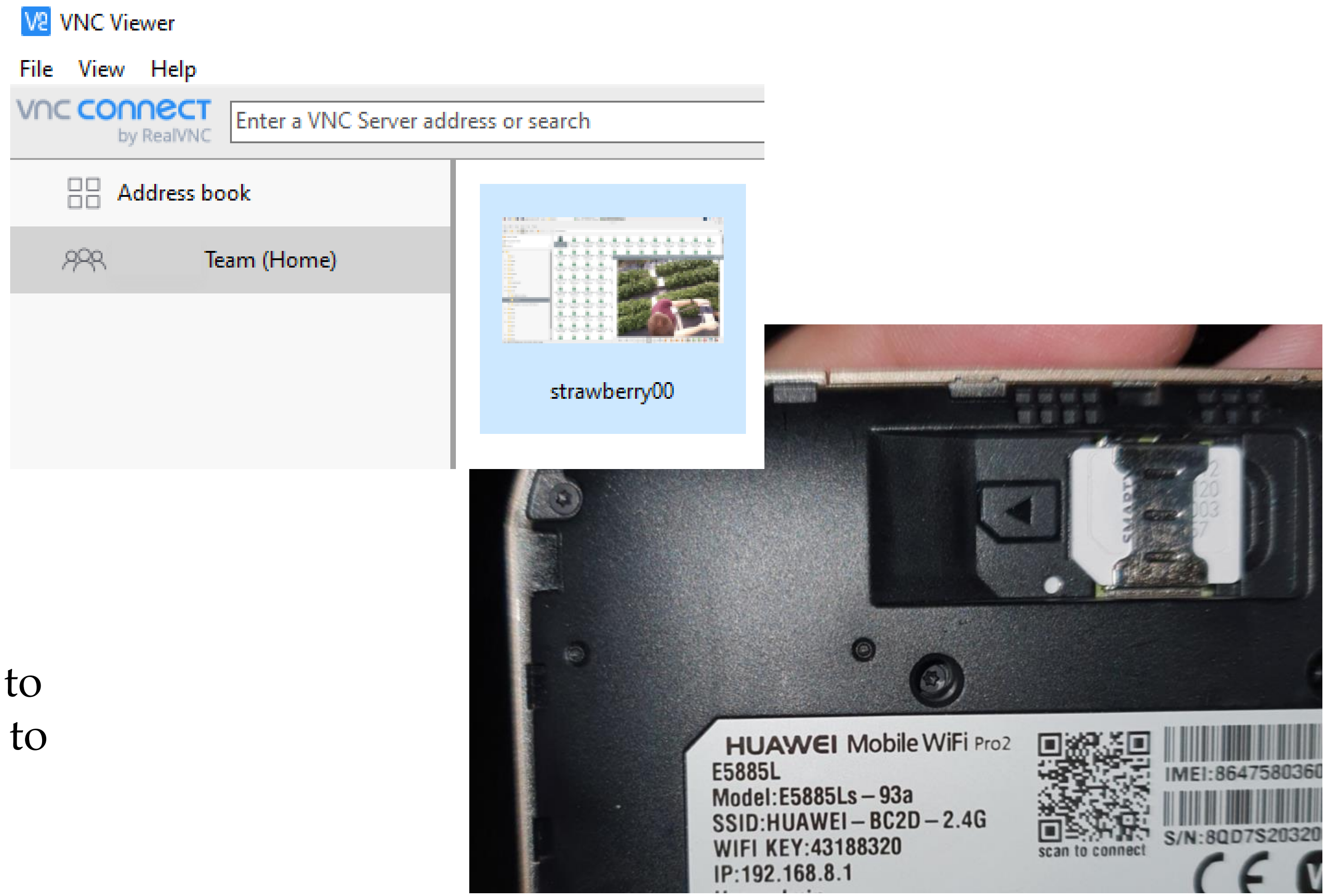

Figure 6. a, Top-left – The client used to connect remotely to the capture system; b, Bottom-right – The mobile Wi-Fi device that was used during the project.

The system was accessible via VNC to remotely connect to the system (figure 6a) to make changes to things like image resolution, capture frequency or to view a live image of the crop from any of the connected modules.

A mobile Wi-Fi device (figure 6b) was used to obtain a connection to the internet whilst also allowing all capture modules to communicate with the network attached SSD.

Discussion

The system was in place over a 13 week period, during which time there was an early Wi-Fi configuration change required to stop the mobile internet device from entering standby.

The RPI devices positioned throughout the tunnel (figure 7) captured the overlapped images which were saved to a network attached SSD, the renewable power system functioned as designed without issue.

By using a platform such as the Raspberry Pi, any data capture project could also take advantage of the GPIO pins and also capture additional data including, but not limited to, environmental data including temperature, humidity, growing medium moisture levels, light levels and EC readings for the growing medium.

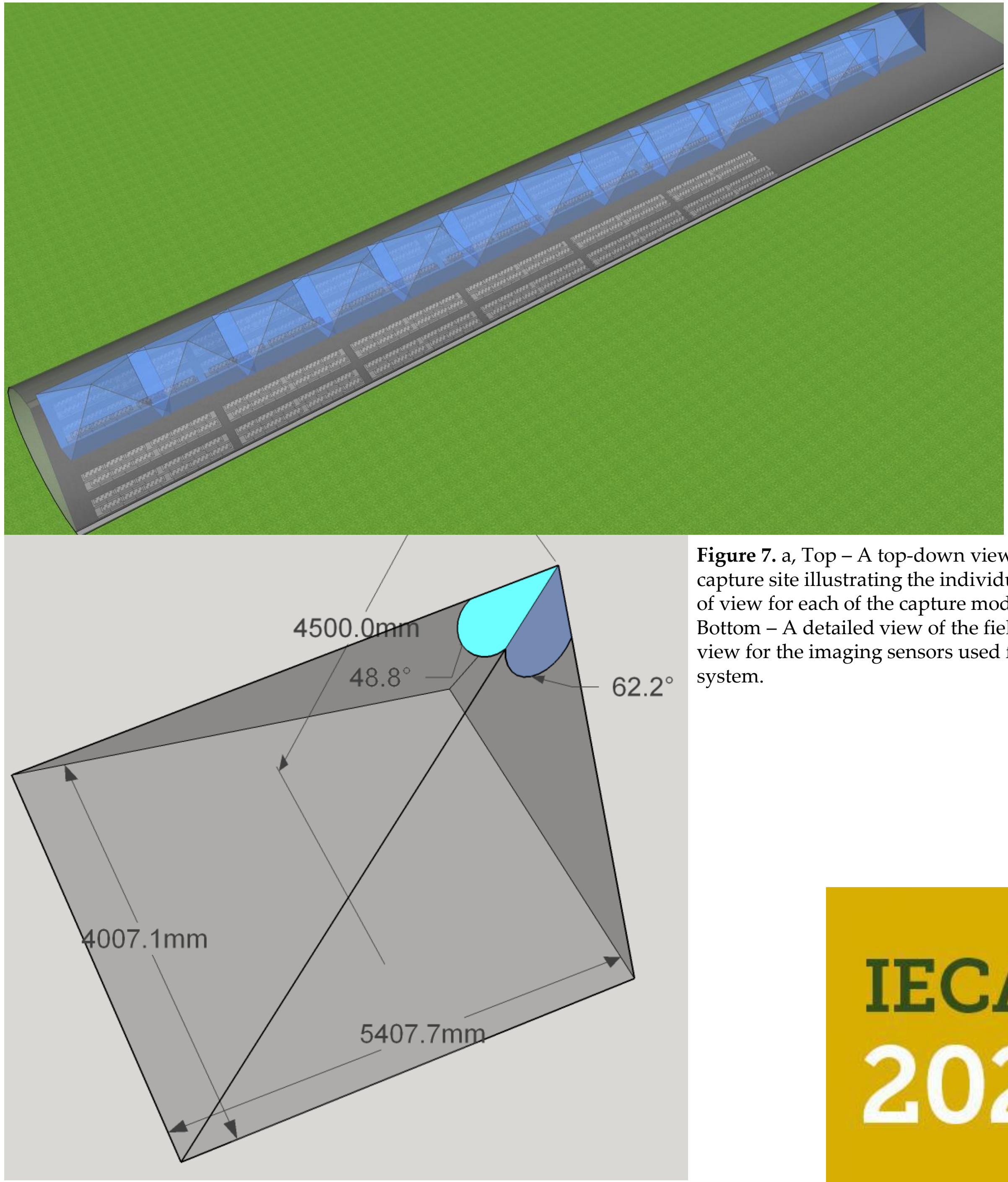

Figure 7. a, Top – A top-down view of the capture site illustrating the individual field of view for each of the capture modules; b, Bottom – A detailed view of the field of view for the imaging sensors used for the system.

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Discussion

Cost per module

Module	Case[1]	Mounting Bracket[1]	RPI	Camera Cable	Camera	Power Cable	TF Memory Card	Total Price
RPI 3B Module	1.15	0.23	33.9	1.5	23.1	2.5	7	69.38
RPI Zero Module	0.74	0.22	13.5	4	23.1	2.5	7	51.06

[1]Cost of 3D printer filament used, all other prices taken from www.thepihut.com [18].

Table 1. Cost breakdown for each capture module.
(Prices as of March & April 2020)

This system is modular and can support upto 24 individual capture devices.

To cover a 70m tunnel on both sides would require 5 additional "clusters" (1 Pi3B & 2 PiZero modules), and can be connected to a single Wi-Fi hotspot (the one used here can support 32 devices)

Cost estimate for a full tunnel coverage would come to approx. £2928 (tables 1, 2 & 3), however further cost reductions can be made by substituting all but one of the Pi3B modules with PiZero modules, this would give a reduction of £63 bringing the total cost to approx. £2865 for same duration.

Data Connectivity Cost

Module	Per Month Y/N	Price
Wi-Fi Hotspot	N	128.76
Unlimited Data Sim	Y	20

Table 2. Cost breakdown for data connection. *(Prices as of March & April 2020)*

Power Generation and storage cost per system (max 8 clusters or 24 modules)

Module	Price
Solar & Wind kit [19]	666.79
110AH Battery [20]	44.06
100m 16A Cable	60
DC-DC Buck Convertor (pk 6)	8.99
12v IP67 Connectors (pk 20)	10.99

Table 3. Cost breakdown for power generation and power storage system. *(Prices as of March & April 2020)*

Conclusions

- This is a low-cost data collection system that is able to operate anywhere in the world where there is access to the sun and a mobile phone signal.
- Use cases could be from simple image data collection (figure 8) through to an integral part of an automated crop management system.
- Deployment of this was ideal for use on a “restrict access” crop such as the one used in this trial, but also removed the need for physical visits to site for data capture during a worldwide pandemic.

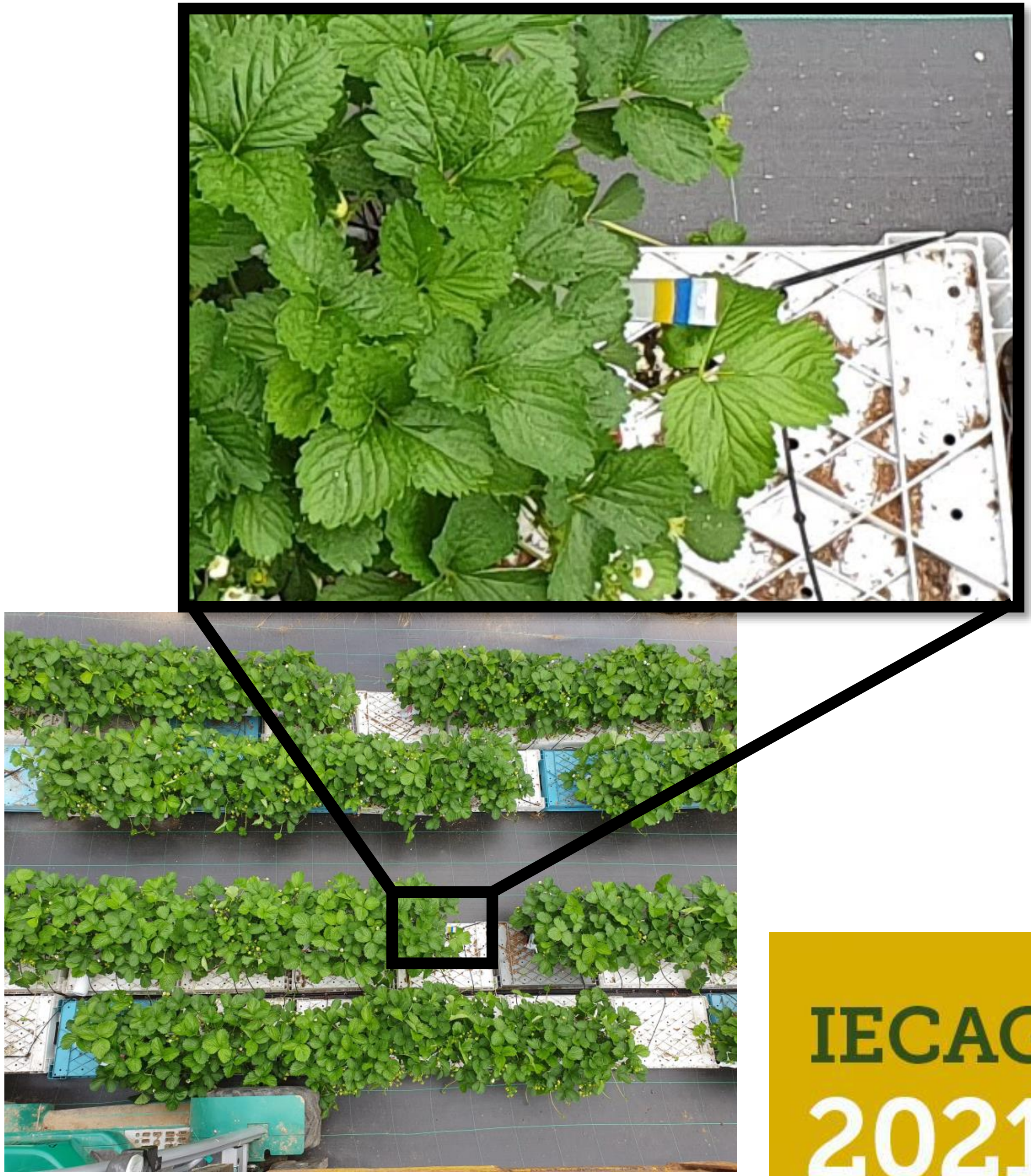

Figure 8. Example of the image data captured using the system.

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