AHDB
HORTICULTURE

Grower Summary

SF 144

Early detection of stress in strawberry plants using hyperspectral image analysis

Final 2017

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

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Project title:	Early detection of stress in strawberry plants using hyperspectral image analysis
Project number:	SF 144
Project leader:	Andrew French University of Nottingham, Jubilee campus, Wollaton Road, Nottingham, NG8 1BB
Report:	Final report, May 2018
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Location of project:	University of Nottingham East Malling Research
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Date project commenced:	12 May 2014
Date project completed:	30th April 2018

GROWER SUMMARY

Headline

- Hyperspectral imaging has been investigated as a means of detecting the onset of plant stress in strawberry.

Background and expected deliverables

The aim of this project was to investigate the use of hyperspectral imaging to analyse and detect the onset of stress in strawberry plants. Such stresses might relate to certain major diseases, common pests or environmental conditions.

Hyperspectral imaging is a challenging technology to work with. It is not a 'point and click' technology: capturing images themselves is a challenge, and the resulting dataset is large and complex. Lighting, calibration and the 3D structure of the plant being imaged can have significant effects on the resulting interpretation of the data.

A hyperspectral image contains both spatial and spectral information, which can be represented in three dimensions. The spatial information is stored in the pixels location along the *x*- and *y*-axes, and the light spectrum reflectance is represented along the z-axis (See Figure 1 in the Science Section of this report).

Unlike a point-source spectroradiometer, a hyperspectral camera measures many reflectance samples throughout a full image of the subject and unlike a *multi*spectral sensor, it is able to record reflectance at many hundreds of wavelength positions, typically extending into at least the visible and near-infrared regions of the spectrum. Hyperspectral data is therefore large in size, especially when multiple plants are imaged for several days. A scan of a single plant could easily be a gigabyte or more in size. If the whole spectrum range is analysed then the process will take considerably longer than selecting several particular wavelengths to analyse. There is a lot of information contained in the data, which could be valuable; the challenge is finding a way to analyse it.

To investigate the potential of hyperspectral imaging to detect stress, a suitable stress to study was first identified. Strawberry plants were subjected to powdery mildew, two-spotted spider mites and drought to capture a time series of how the plants respond to these biotic and abiotic stresses. From these investigations, drought provided the appropriate balance between ease of control of the stress itself over a time series and the resulting nature of the visible/hyperspectral effects seen in the data. The images were collected using hyperspectral cameras, including both the spatial information (the location of the pixels in the image) and spectral information (the narrow bands of contiguous wavelengths from visible light to near infra-red light). Imaging of the plants took place at NIAB EMR and the University of Nottingham.

Once the images were captured, the strawberry plants needed to be identified in the images using a technique known as 'segmentation'. This involved labelling objects (leaves, in this case) in the image by finding regions of similar properties such as colour, shape or texture. Once the leaves have been located in the images, the hyperspectral information can be extracted from these regions and analysed over time. This avoids taking measurements from pixels of the background (such as pots or soil) rather than plant material.

In this project, though, hyperspectral reflectance was found to be dependent on certain 3D properties of the plants: factors such as the height and angle of the leaf could affect the hyperspectral reflectance profile. Therefore, 3D information was also collected in order to build a 3D model of the plant. The 2D hyperspectral data was then mapped onto the 3D plant model. To take hyperspectral measures from a plant, the 3D model was used to select a set of leaves on the plant which were likely to produce good quality hyperspectral readings: leaves which are flat, towards the top of the plant, and near the centre of the image.

Readings from these selected leaves were then recorded, and equivalent leaves manually selected from the plant throughout the time series to provide stress response data.

Summary of the project and main conclusions

A new analysis pipeline was developed to automatically take hyperspectral measures from plant leaves. Leaves were selected using information from a 3D plant model which helped remove undesirable leaves from the analysis.

This pipeline was found to produce similar results to the more labour intensive manual approach to data analysis, suggesting such a pipeline could be incorporated in a future hyperspectral imaging system. However, despite the new analysis pipeline, and careful control of experimental and imaging conditions, it was hard to determine clear and robust indicators of the early onset of drought, despite some visual indication in the hyperspectral profiles, suggesting that a difference in NIR reflectance may be present over a period of days. The results are considered in more detail in the Science Section of this report.

For those considering use of a hyperspectral system to determine stress, this study advises:

- To consider the type of hyperspectral camera system carefully, as several systems exist, and they work in different ways.
- To consider if 3D information will need to be taken into account when imaging plants.
- To carefully control lighting during imaging, and additionally calibrate using a reflectance white balance target.
- To consider where spatially on a plant a hyperspectral measure originates, as this can affect the reflectance profile: factors such as shadowing and orientation of the leaves may affect the data.
- Acknowledging that there is unlikely to be an ‘off the shelf’ analysis approach for a particular stress. Methods are still in active development and more complex software packages to support analysis are likely to become available over time.

Financial benefits

No firm financial benefits can be drawn from this early research into hyperspectral imaging in soft fruit. Investment in hyperspectral imaging methods requires outlay in both the hardware technology and suitable, potentially complex, analysis methods. As technology develops, the cost of the hardware drops. However careful use and analysis is still of primary importance when using this technology.

Action points for growers

- There are no direct action points for growers resulting from this work.