1st Call for Funding: Dr Bo Li – NIAB

October 7, 2020 (updated October 8, 2020)
Investigation of microwave imaging for internal fruit quality and below-ground phenotyping

---

Total Fund Requested – £24,783

Project Summary

Food demand is expected to increase anywhere between 59% and 98% by 2050, and consumers are becoming increasingly health conscious about their lifestyles and diets. This will shape agricultural markets in ways we have not seen before. As such, fruit and vegetable producers will face the challenge to produce high yield and quality products, and this requires rapid advancement in phenotyping for both breeding and postharvest handling. Plant phenotyping has been rapidly developed in recent years along with the development of genetic analysis, but there are still limitations with regards to assessing fruits' internal quality and below ground phenotyping (Clark et al., 2003). Currently these still largely rely on manual assessment, which is destructive, time-consuming and always subjective. Non-destructive imaging techniques including X-rays, magnetic resonance imaging (MRI) and computed tomography (CT) have also been applied for plant phenotyping to improve the visibility of internal structures of fruits and below-ground, but the drawbacks such as high cost and safety risk limit their applications (Herremans et al., 2014).

Microwave radiation is the section of the electromagnetic spectrum beyond radio waves, usually having frequencies from 0.3 GHz up to 300 GHz. These waves have been known for a long time and have been harnessed to improve applications such as communications (satellite, TV, Bluetooth, etc.), radar, radio astronomy and home cooking (Meaney et al., 2000). The interaction of electromagnetic waves and matter depends on dielectric properties which can be directly related to various types of biological constituents due to their varying degree of water content. The strong penetration ability of signals at different frequencies within the microwave range makes microwaves a promising technology for medical diagnosis such as breast tumour detection, and security check such as body scanners in airports. Compared with traditional X-rays, MRI and CT scanning, microwave imaging is safe and low-cost; whilst compared with THz imaging, which also has good penetration ability, microwave signals are less absorbed by the water content in fruit or soil (Peng et al., 2013). Dr. Kosmas is leading a microwave imaging group at King's College London (KCL), and is currently developing a prototype microwave imaging system for the detection of brain stroke, which is funded by EPSRC and Innovate UK. The group has also recently joined a 3.3 million Euros microwave medical imaging project, which is training 13 early-stage researchers in Europe to develop portable and low cost medical devices allowing real-time monitoring of therapy efficacy and pathology evolution.

For this problem, a recently developed radar algorithm based on Huygens principle will be employed and optimised for internal image reconstruction of the fruits. The technique will not aim to reconstruct the exact internal field, but rather to make use of the difference in dielectric properties between the different regions of the fruit to detect and localize any abnormalities inside them. The algorithm measures the field on the external surface of the object and back-propagates this field numerically into the imaging domain, thus reconstructing the internal field. Then, through combining all the gathered information from all the transmitting positions and receiving positions and the individual frequencies, the final image is acquired. The experimental setup will be designed and optimised to be cost and time efficient, and only one transmitter and one receiver antenna will be used in these measurement.

Dr Bo Li is leading the image analysis group in NIAB EMR and developed several imaging techniques for fruit phenotyping including 2D, 3D and hyperspectral imaging. For the root architecture analysis, Dr Li developed 2D image analysis software to quantify multiple parameters such as total length, convex hull, average parameters and solidity in a high-throughput manner. Even though the plant was grown in the rhizotron (Nagel et al., 2012), most parts of the root were still occluded by soil. Other advanced imaging techniques such as Computerised Tomography (CT) scanning and Magnetic resonance imaging (MRI) were also applied to root phenotyping, but they are both time consuming, expensive and potentially harmful to researchers.

Internal disorder of apple is considered a major defect by retailers, with consignments subject to rejection if more than 2% of fruit display the disorder. MRI was applied in research but due to the high cost, it is not practical for online sorting system (Khatiwada et al., 2016). Spectroradiometer is applied to detect apple internal disorder, but previous experiment in NIAB EMR show that limited accuracy was achieved and it is hard to quantify the severity of disorder for breeding practice.

Current measurement of nitrogen use efficiency (NUE) of potato cultivars by the large scale field phenotyping of above ground canopy is time consuming and labour-intensive, also affected by management strategies. Visualisation of potato tuber in the pots by microwave imaging can move most of the experiments from field to glasshouse, which can largely reduce the labour required and improve the accuracy of phenotyping.

Early 2019, preliminary experiments were carried out by NIAB EMR and KCL, and microwave imaging showed promising results in fruit seed detection and the separation between jelly and flesh in tomato as shown in figure 1 and 2.

In order to investigate the feasibility of microwave imaging for assessing fruits' internal quality and below-ground phenotyping, KCL will modify the existing microwave imaging platform (Fig. 1) and optimise the imaging algorithm; whilst NIAB EMR will be responsible for the fruit materials supply, post image processing and project management. Four experiments will be carried out to test the system including:

1. Strawberry root visualisation in compost with various water levels.
2. Non-destructive apple internal browning detection.
3. Non-destructive quantification of the percentage of jelly and flesh in tomato.
4. Potato tuber visualisation in pot.

These experiments will be in line with the projects funded by Innovate UK, BBSRC and Newton grant in NIAB EMR and all the experimental materials will be provided by NIAB EMR.

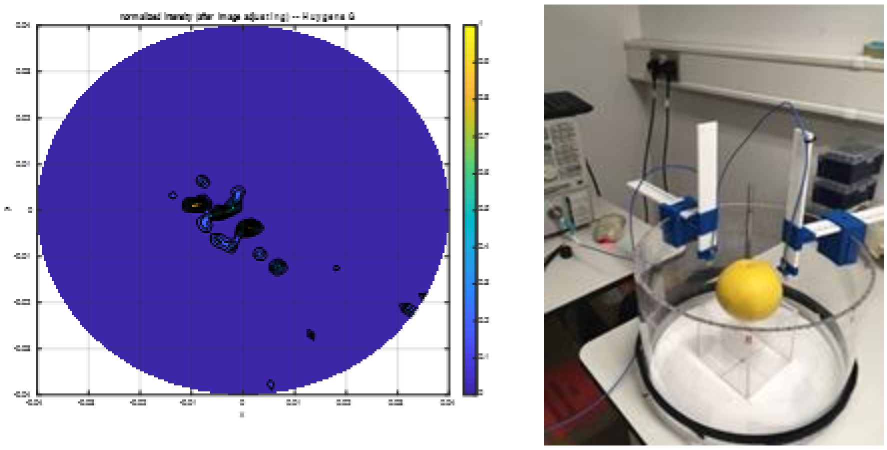

Figure 1. Prototype microwave imaging platform developed at KCL for the detection of brain stroke (left), and resulting image of seed detection in grapefruit (right).

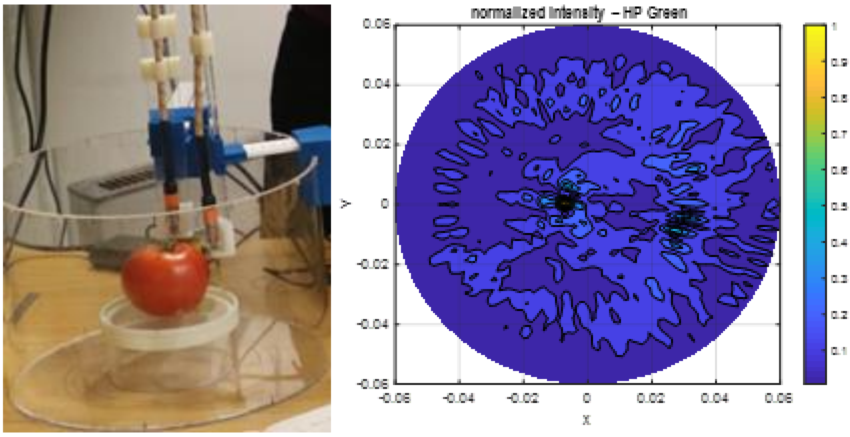

Figure 2. Separation between jelly and flesh in tomato.

Timeline for Activities – Max 24 Months

The total length of the project will be **12 months**.

WP1. Microwave imaging platform modification. (KCL, M1 – M3)

Task 1.1. Design and construction of customised prototype for fruit imaging.

Task 1.2. Validation of the prototype functionality through phantom measurement.

WP2. Radar algorithm optimisation. (KCL, NIAB EMR; M1 – M6)

Task 2.1. Investigation of the optimum frequency range and bandwidth.

Task 2.2. Optimisation of the algorithm through resolution enhancement and artefact removal techniques.

Task 2.3. Image post-processing software development.

WP3. Testing the microwave imaging system with four proposed experiments. (NIAB, KCL; M6 – M11)

Task 3.1. Non-destructive apple internal browning detection.

Task 3.2. Non-destructive quantification of the percentage of jelly and flesh within tomato.

Task 3.3. Potato tuber visualisation in soil.

Task 3.4. Strawberry root visualisation in compost.

WP4. Report writing, paper dissemination and discussion of future collaborative grant application. (NIAB EMR, KCL; M12)