Project title and location: Development of Agri-diagnostic techniques for early detection of below ground crop diseases using integrated sensing approaches.
Student will be based in Newcastle in School of Natural and Environmental Sciences but will spend reasonable time at Fera as well.

IAFRI background: The Institute for Agri-Food Research and Innovation (IAFRI) is a joint venture between Newcastle University and Fera Science Ltd and a unique model for how universities can work with private sector research organisations. It operates under a private-public ownership to deliver both public good research and services as well as innovation and wealth creation in strategically important industrial sectors in the UK. Students will have a unique opportunity to benefit from supervision and facilities at both the Newcastle and Sand Hutton campuses to deliver research with real-world impact.

Lead Supervisors (and contact): For more information and details on how to apply please contact Ankush Prashar (ankush.prashar@newcastle.ac.uk) orThomas Prior (Thomas.Prior@fera.co.uk)

Key research gaps and questions: The most straightforward or used method to determine endo-parasitic nematode infestation is visual examination of plant roots for the presence of typical symptoms. However, visual destructive sampling approaches are invasive and impractical for large-scale use. Additionally, below-ground visual symptoms develop gradually with time and vary in size depending on population levels, different pathogen species and susceptibility of host plants.
As an example in potato which will be the main crop in this project, Root knot nematodes (RKNs) cause specific galls on the roots of parasitized plants with both RKN and PCN (Potato Cyst Nematodes) root infestation resulting in non-specific effects on the canopy. These effects are also similar to the signs of drought or nutrient depletion, with PCN only able to be observed with the naked eye in the last stages of nematode infestation in roots.
Thus, there is a need to develop diagnostic systems, which can help in early detection of these diseases using aboveground/canopy characteristics whilst improving understanding of the aboveground-belowground trait linkages.
Broadly, this project aims to answer whether we can utilize a high throughput integrated sensor phenotyping approach for early detection of pest/disease in potato and their discrimination from other stresses by using the understanding of the aboveground-belowground traits' interaction.

Project Description: Physiological characters (e.g photosynthesis, plant nutrition and hormonal functions etc) are excellent indicators of many traits (e.g. pest/disease resistance, quality & yield) but are difficult to measure and quantify, especially under field conditions.
Plant-parasitic nematodes have a major impact on global food production with an estimated annual loss of about €110 billion worldwide. Root-knot nematodes (RKN; *Meloidogyne spp.*) and potato cyst nematodes (PCN; *Globodera pallida* & *G. rostochiensis*) have high agronomic impact and are considered high-impact plant-parasitic nematodes. Characterising root phenotypes that confer resistance to root pests and disease is challenging, and involves destructive plant harvesting, and so is understanding the interaction between above ground canopy traits and below ground rooting traits for agri-diagnostics. However, studies have shown that changes in shoot and leaf physiology can provide an indirect indicator of root processes below ground. Infrared thermography (IRT) was recently shown to be a reliable tool for monitoring plant stress in potato by measuring changes in canopy temperature associated with altered stomatal conductance (Prashar et al, 2013; Prashar et al., 2014, Prashar and Jones, 2016). Studies on nematode infestation of plants such as potato (*Solanum tuberosum*) have also been shown to influence plant physiological parameters. Susič et al. 2018 demonstrated the potential of spectral imaging to detect

Meloidogyne spp. infestation, with other examples available in sugarbeet, soyabean and cotton. Thus, it is possible to detect specific (biotic) stresses but difficulties arise when discriminating stresses from different pathogens. Similarly, abiotic stresses e.g. water stress, are more accurately detected, although the differentiation between these stresses is crucial when working with soil properties and below ground traits.

Thus, this project aims to use the relationship between physiological ground truthing parameters and remote sensing techniques in the form of integrated spectral and thermography imaging sensors to accurately detect disease infestation in potatoes and understand its application in reliably discriminating between abiotic drought stress symptoms and biotic stress caused by the nematodes/other root diseases, the reason being a high similarity of above-ground effects caused by both stressors on the plant canopy. With the aim to evaluate sensing approaches, and develop methodology where canopies are assessed as indirect indicators of root phenotypes and to monitor and detect early root stress responses, different physiological traits will be evaluated under both control and field conditions with following objectives in mind.

1) Evaluate the utility of high-throughput phenotyping techniques to predict canopy traits and relationship to yield in field conditions.
2) Conduct case studies for early disease detection under field scenarios for nematodes.
3) Determine the interactions between water use/stress traits and susceptibility to pests/disease and interaction with soil physical properties.
4) Determine association between stress response and yields and understand how stress response mechanisms contribute to crosstalk

Prashar, A., Yildiz, J., McNicol, J.W., Bryan, G.J. and Jones, H.G. (2013) 'Infra-red Thermography for High Throughput Field Phenotyping in Solanum tuberosum', *PLoS One*, 8(6), pp. e65816, 65811-65819.

Prashar, A. and Jones, H.G. (2014) 'Infra-Red Thermography as a High-Throughput Tool for Field Phenotyping', Agronomy, 4(3), pp. 397-417.

Prashar, A. and Jones, H.G. (2016) 'Assessing Drought Responses Using Thermal Infrared Imaging', Methods Mol Biol, 1398, pp. 209-19.

Susič, N., Žibrat, U., Širca, S., Strajnar, P., Razinger, J., Knapič, M., Vončina, A., Urek, G. and Gerič Stare, B. (2018) 'Discrimination between abiotic and biotic drought stress in tomatoes using hyperspectral imaging', Sensors and Actuators B: Chemical, 273, pp. 842-852.

Wheeler, T.A. and Kaufman, H.W. (2003) 'Relationship of Aerial Broad Band Reflectance to Meloidogyne incognita Density in Cotton', J Nematol, 35(1), pp. 48-57.

Desired skills: The project should appeal to range of students with experience in the area of crop phenotyping, precision agriculture, remote sensing, plant pathology and/or other related plant science area. We are seeking a talented student with interest in image analysis, scientific programming and machine learning.

Candidates with a background in engineering, physical sciences or computer science and interest in its application in Agriculture or Plant science are encouraged to apply.

Minimum qualification requirement will be a 2:1 honours degree.

Candidates outside of the UK /EU are welcome to apply. However, evidence of ability to pay additional tuition (above home / EU levels) and visa fees for non-UK/EU students is required. Band 7.5 English Language requirements (IELTS 7.0 overall)