University of Nottingham
UK | CHINA | MALAYSIA

UKRI Biotechnology and Biological Sciences Research Council

WGIN Stakeholders' Meeting

6 February 2023

Unlocking the potential of wheat grain heterogeneity using machine vision

Professor Ian Fisk

Dr John Foulkes; Dr Rahul Bhosale

Dr Simon Griffiths; Prof Malcolm Hawkesford

University of Nottingham

FOOD FLAVOUR
UNIVERSITY OF NOTTINGHAM
UNIVERSITY OF ADELAIDE

Unlocking the potential of wheat grain heterogeneity using machine vision

University of Nottingham : FISK(PI), Foulkes, Bhosale

John Innes Centre: Griffiths

Rothamsted Research: Hawkesford

Partners Organisations:

- DSV UK Ltd.
- Campden BRI,
- Buhler
- New Food Innovation
- Carrs
- Leco
- AB Mauri
- University of Adelaide
- Australian Institute for Machine Learning

University of Nottingham
UK | CHINA | MALAYSIA

John Innes Centre

ROTHAMSTED RESEARCH

Campden BRI
food and drink innovation

DSV

BÜHLER

nfi

LECO
EMPOWERING RESULTS

CARR'S
GETTING THE BEST OUT OF WHEAT

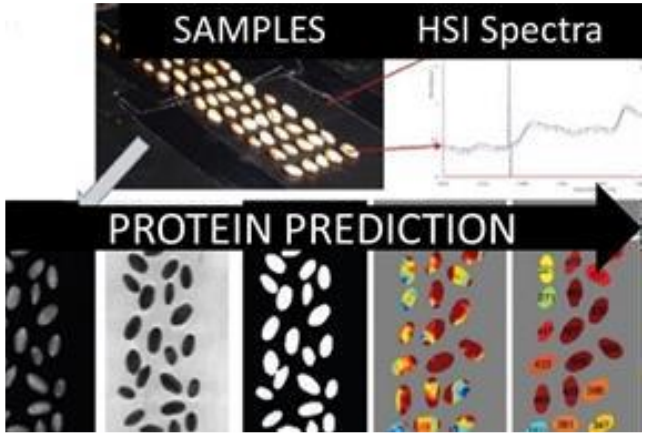
AB MAURI
Passionate About Baking™

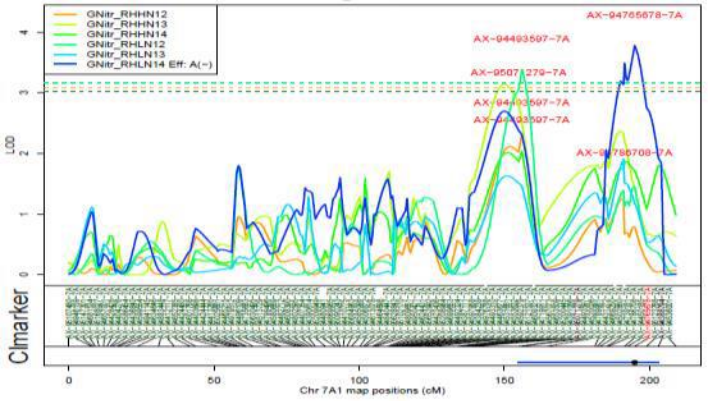
AUSTRALIAN INSTITUTE FOR MACHINE LEARNING

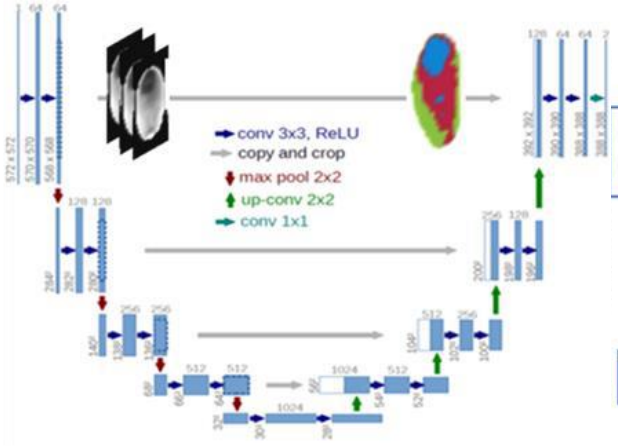
THE UNIVERSITY of ADELAIDE

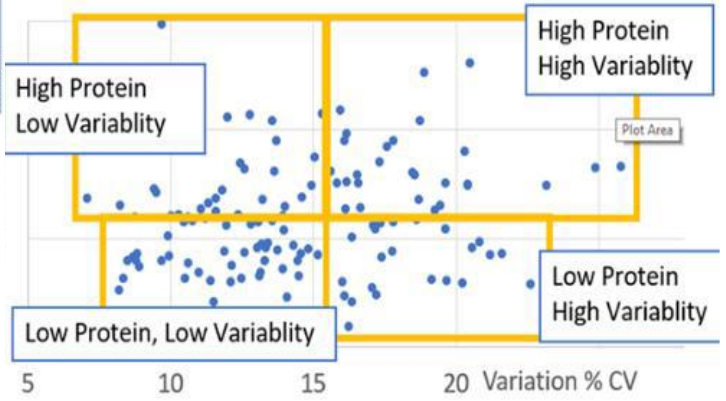
Project Objectives

We will develop a novel single seed characterisation technology based on hyperspectral imaging (HSI) integrated with next generation machine learning and develop the tools to upgrade significantly UK wheat grain quality (increase homogeneity of protein quality and quantity, enhance micronutrients and flavour potential).

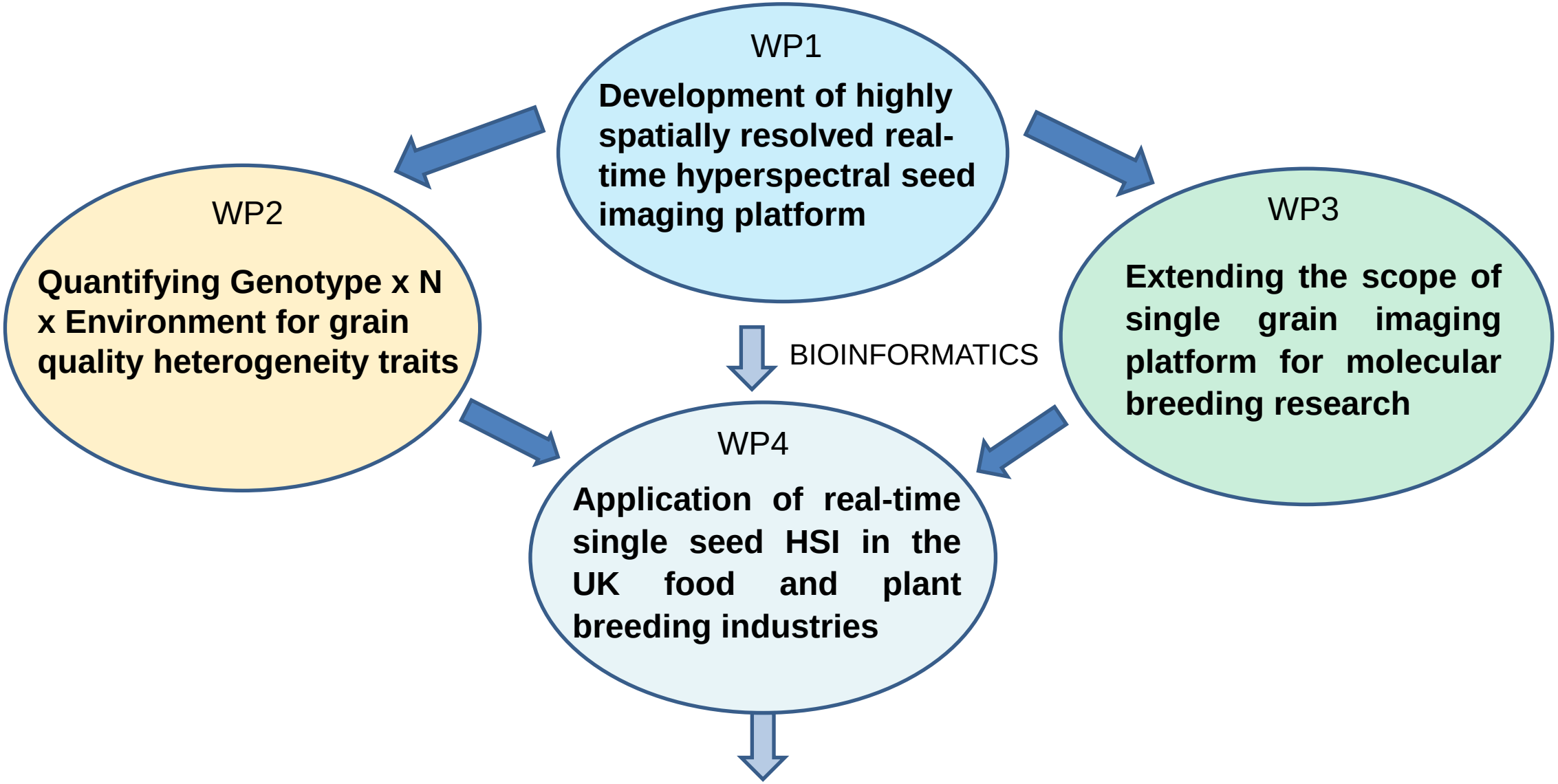








Relationships between Work Packages



WP1 :Development of highly spatially resolved real-time hyperspectral seed imaging platform

Objective 1: Develop a seed hyperspectral imaging technology (HSI) integrated with machine learning to improve uniformity of grain quality traits in wheat

Task 1.1 **Development of a push-broom hyperspectral imaging system**

Task 1.2 **Formulate a deep learning network suitable for real time interpretation**

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

LECO
EMPOWERING RESULTS

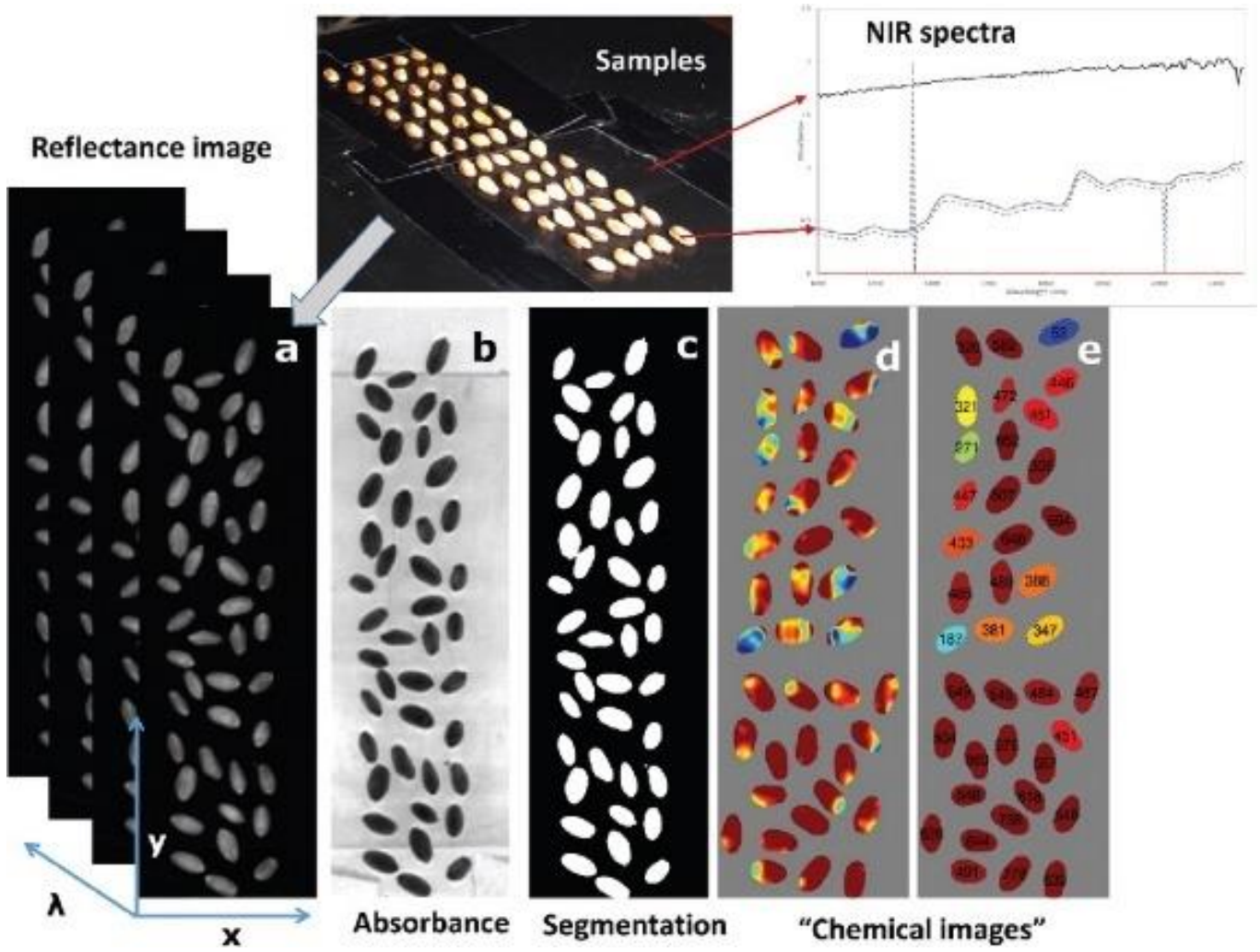
BÜHLER

Campden BRI
food and drink innovation

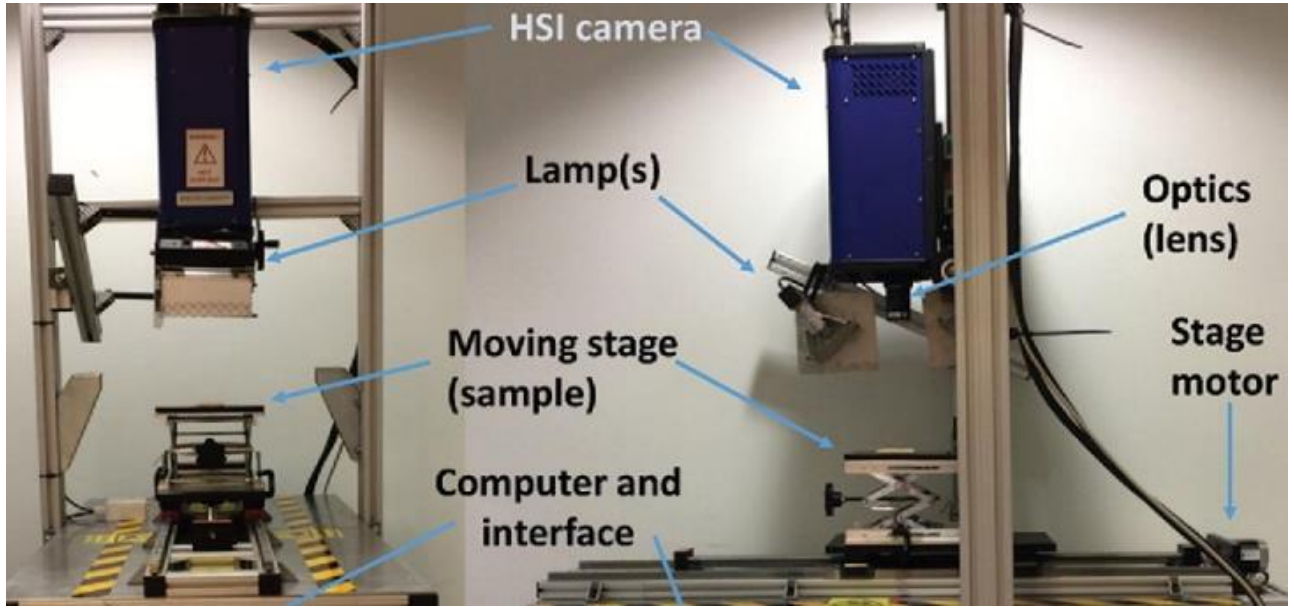
AUSTRALIAN INSTITUTE FOR MACHINE LEARNING

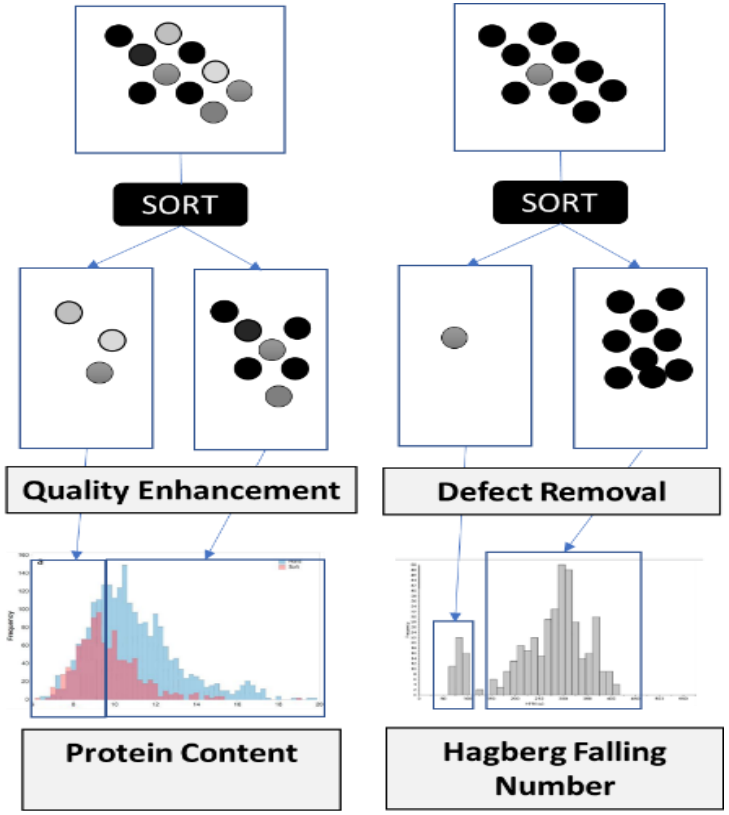
Single grain hyperspectral imaging screening

Hyperspectral imaging provides information on the spatial distribution of major chemical constituents across a sample's surface

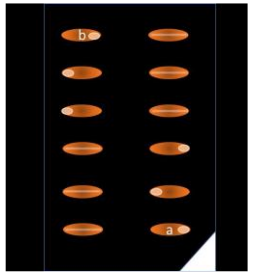


Single grain hyperspectral imaging (HSI) screening





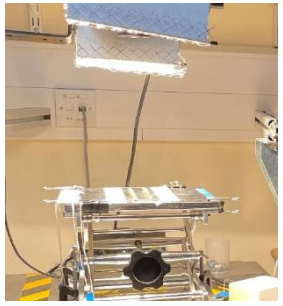
The University of Nottingham and our collaborators are leaders in hyperspectral characterisation of single-seed sorting of food quality traits.



Illustration

- 12 grains from each line imaged

(6 crease-down, 6 crease-up)



Sample (scanning)

We have applied HSI for the non-destructive prediction of grain protein. Protein ranged from 6%–20% (on a single grain basis) and regression models (R^2 = 0.82) were successful (Caporaso, 2018).

WP2 : Quantifying Genotype x N x Environment for grain quality heterogeneity traits

Objective 2) Screen elite and exotic wheat genotypes, quantify GxNxE) for single grain quality uniformity traits and understand its physiological basis.

Task 2.1 **Define G x N x E for grain heterogeneity traits using existing WGIN grain samples**

Task 2.2 **Understand the physiological basis of G x N x E effects for grain uniformity traits**

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

ROTHAMSTED RESEARCH

John Innes Centre
Unlocking Nature's Diversity

DSV

Task 2.2 Understand G x N x E for grain uniformity traits (Yrs 1 and 2)

- Field experiments testing 12 genotypes at optimum N and low N levels (4 reps) at Nottingham and Rothamsted in 2022-23 and 2023-24
  - Six elite winter wheat RL varieties and six NILs (allelic variation for grain length QTL on in Paragon)
  - Grain assessed for GP%, HFN, starch content etc and single grain HSI screen to quantify the uniformity of grain quality and G x N x E
  - Variance in heterogeneity of grain quality traits tested in relation to phenology, tillering and canopy structure traits affecting ears/plant and spikelets/ear.

Task 2.2 Understand the physiological basis of G x N x E effects for grain uniformity traits

- Intra-spike grain protein homogeneity of 47 breeding parents in the DSV wheat breeding programme assessed (top, middle and bottom of ears) by NIR and HSI for individual grains.

- F2-F4 populations investigated in DSV breeding programme to see if the protein level can be manipulated by selection based on hyperspectral imaging of single grains during the previous generation.

DSV

Dr Matt Kerton

WP3 : Extending the scope of single grain imaging platform for molecular breeding research

Objective 3: Showcase the single grain HSI technology as a molecular breeding tool for functional genomics

Task 3.1 **Determine key genes controlling single grain quality traits**

Task 3.2 **Validate MTAs by developing Near Isogenic Lines (NILs) and evaluation of RILs with altered protein function of target genes**

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

John Innes Centre
Unlocking Nature's Diversity

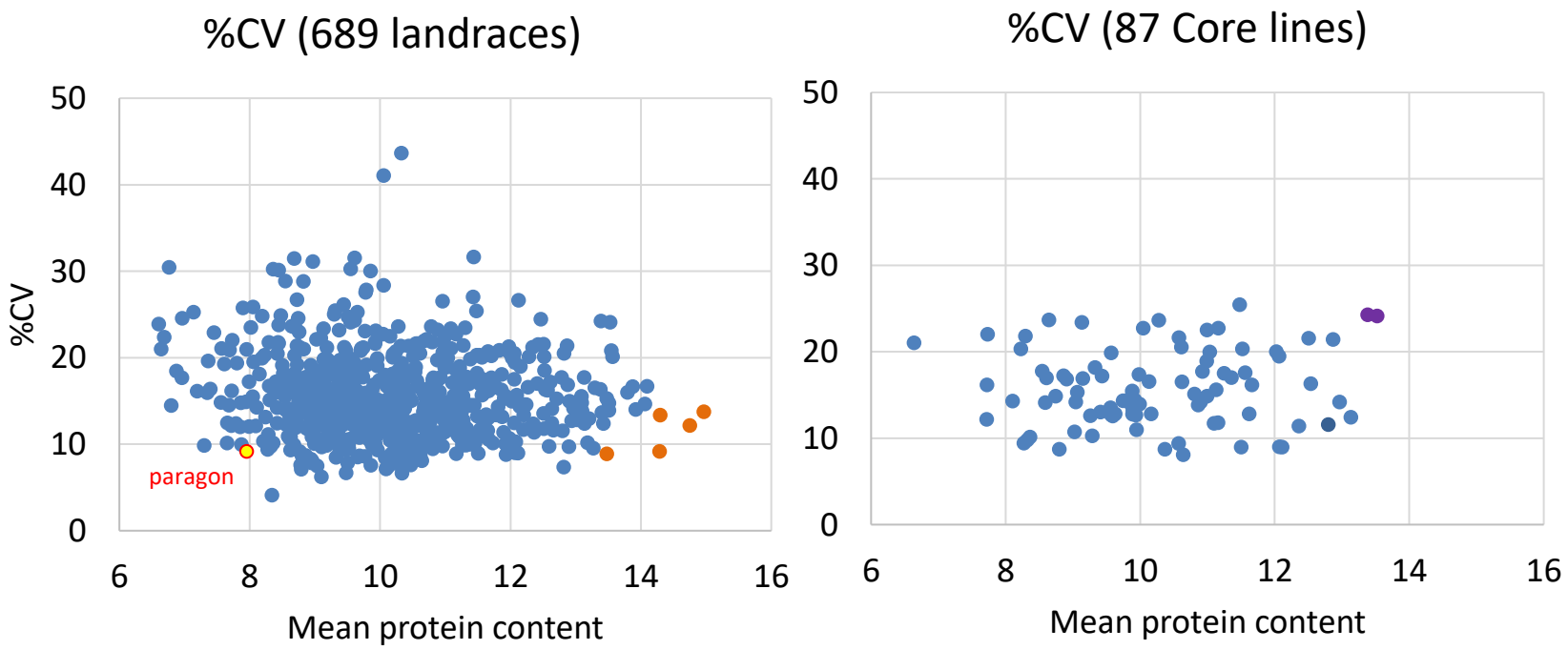
ROTHAMSTED RESEARCH

Campden BRI
food and drink innovation

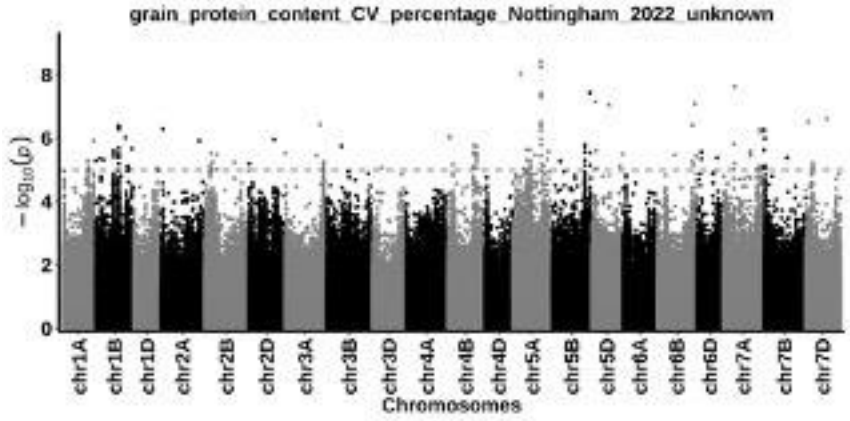
HSI imaging of Watkins landraces

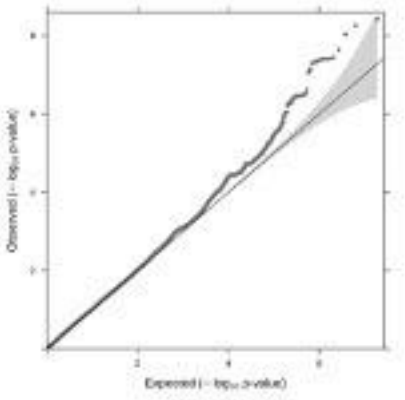
- 123 lines (including 47 core lines) were initially screened using Dumas analysis (12 grains per lines) = <u>1440 datapoints for the predictive model</u>

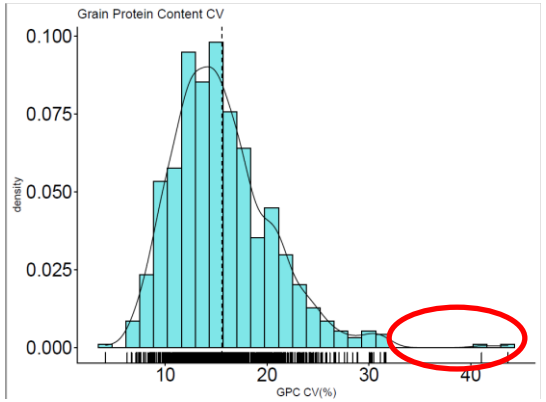
- Out of 826 bread wheat A.E. Watkins landrace collection, 689 lines (including 120) were imaged using HSI and protein content was predicted using the predictive model

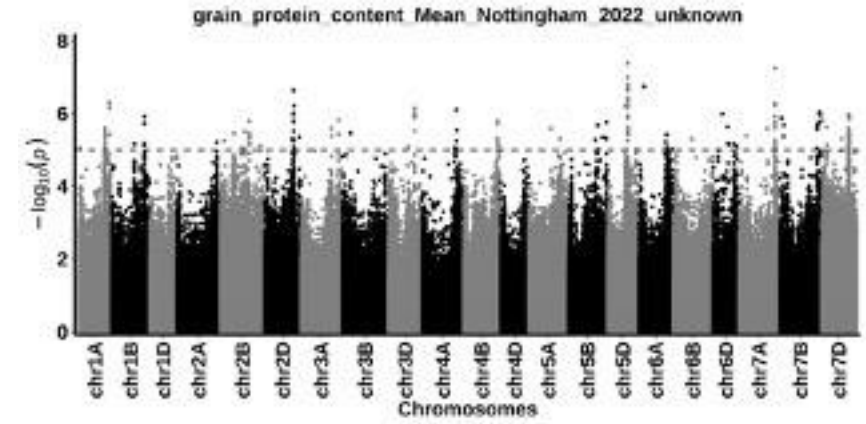


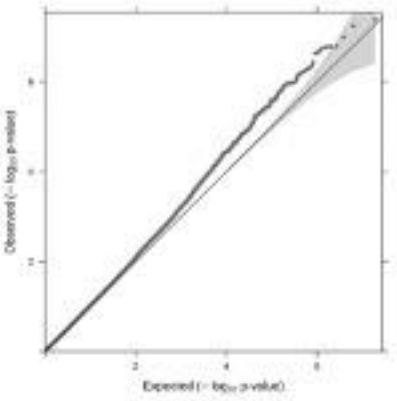
GWAS using predicted GPC of 689 landraces

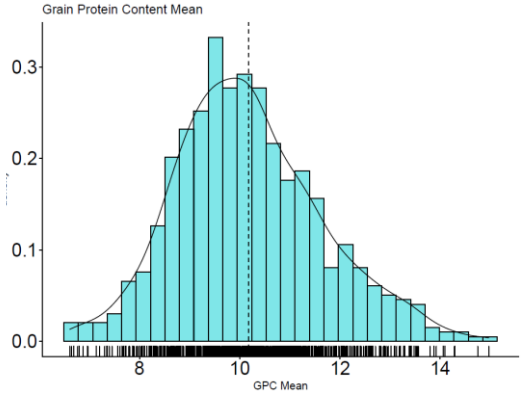












Shifeng Cheng and Simon Griffiths

PhD Student
Luqman Safdar

Task 3.1 Determining key genes controlling single grain quality traits (Yr1-3)

- Screen seeds of (i) Watkins landrace collection (ii) Paragon X landrace NAM population using HSI platform and perform GWAS.
- Prioritise MTA using (i) functional annotation resources (ii) transcriptomics analysis.
- Mapping selected MTAs by screening of one biparental Paragon X Watkins landrac

Task 3.2 Validating MTAs (Yr 2-3)

- Developing/evaluating Near Isogenic Lines (NILs)
- Evaluation of RILs (Recombinant Inbred lines) with altered protein function of target genes

WP4 : Application of real-time single seed HSI in the UK food and plant breeding industries

Objective 4: Apply the hyperspectral seed imaging in the UK food industry; and in plant breeding.

Task 4.1 Develop micro-loaf and prototype breads with increased health credentials
Task 4.2 Develop malted wheat with enhanced flavour and increased health credentials
Task 4.3 Develop digestive biscuits with enhanced flavour and health credentials
Task 4.4 Develop wheat lines in plant breeding with improved grain quality homogeneity

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

CARR'S
GETTING THE BEST OUT OF WHEAT

DSV

Campden BRI
food and drink innovation

AB MAURI
Passionate About Baking™

BÜHLER

Acknowledgements

Biotechnology and Biological Sciences Research Council

Uni of Nottingham
Prof Ian Fisk (IDF) - PI
Dr John Foulkes
Dr Rahul Bhosale
Kate Dugina; Mui Lim ;Jenny Drury

Rothamsted Research
Prof Malcolm Hawkesford
Andrew Riche
David Steele

JIC
Dr Simon Griffiths
Luzie Wingen
Charlie Philip

Buhler
Tim Kelf, Nicola Caporaso

NFI
Alan Marson

Campden
Craig Leadley, Martin Whitworth, Alix Cornish

DSV
Matthew Kerton

Carr's
Julius Deane

LECO
Alan Griffiths

ABMAURI
Jim Hawkridge

AIML
Ehsan Abbasnejad

Adelaide
Scott Boden