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Where Knowledge Grows

Pushing up average wheat yields. What can we achieve and how?

Professor Maurice Moloney
Director and Chief Executive
Rothamsted Research

THE OXFORD FARMING CONFERENCE 4th Jan 2013

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Food Security

'Demand for food is projected to increase by 50% by 2030 and double by 2050'

'The challenge for global agriculture is to grow more food on not much more land, using less water, fertiliser and pesticides than we have historically done'

Sir John Beddington
UK Government Chief Scientific Adviser

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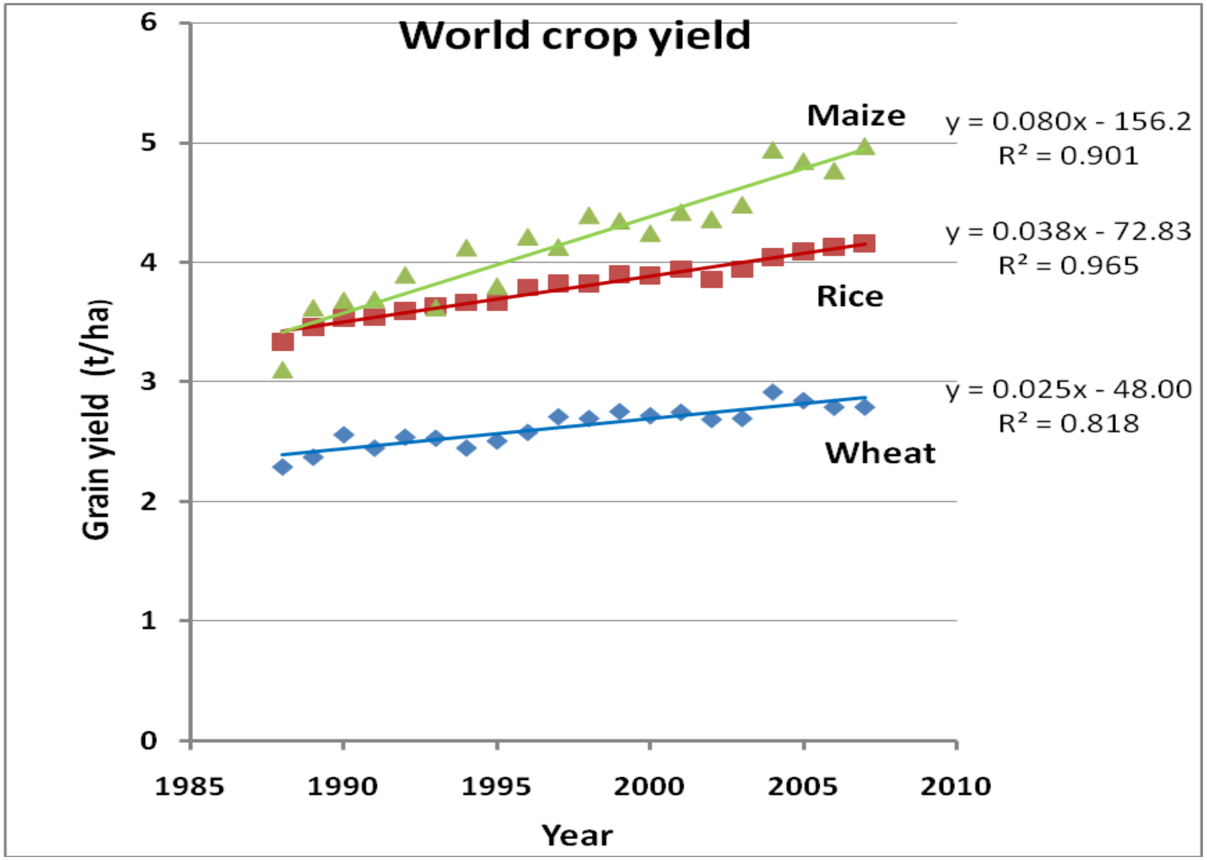
Stagnation of Yield Progress in Cereals?



2%

1%

1%

FAO stats

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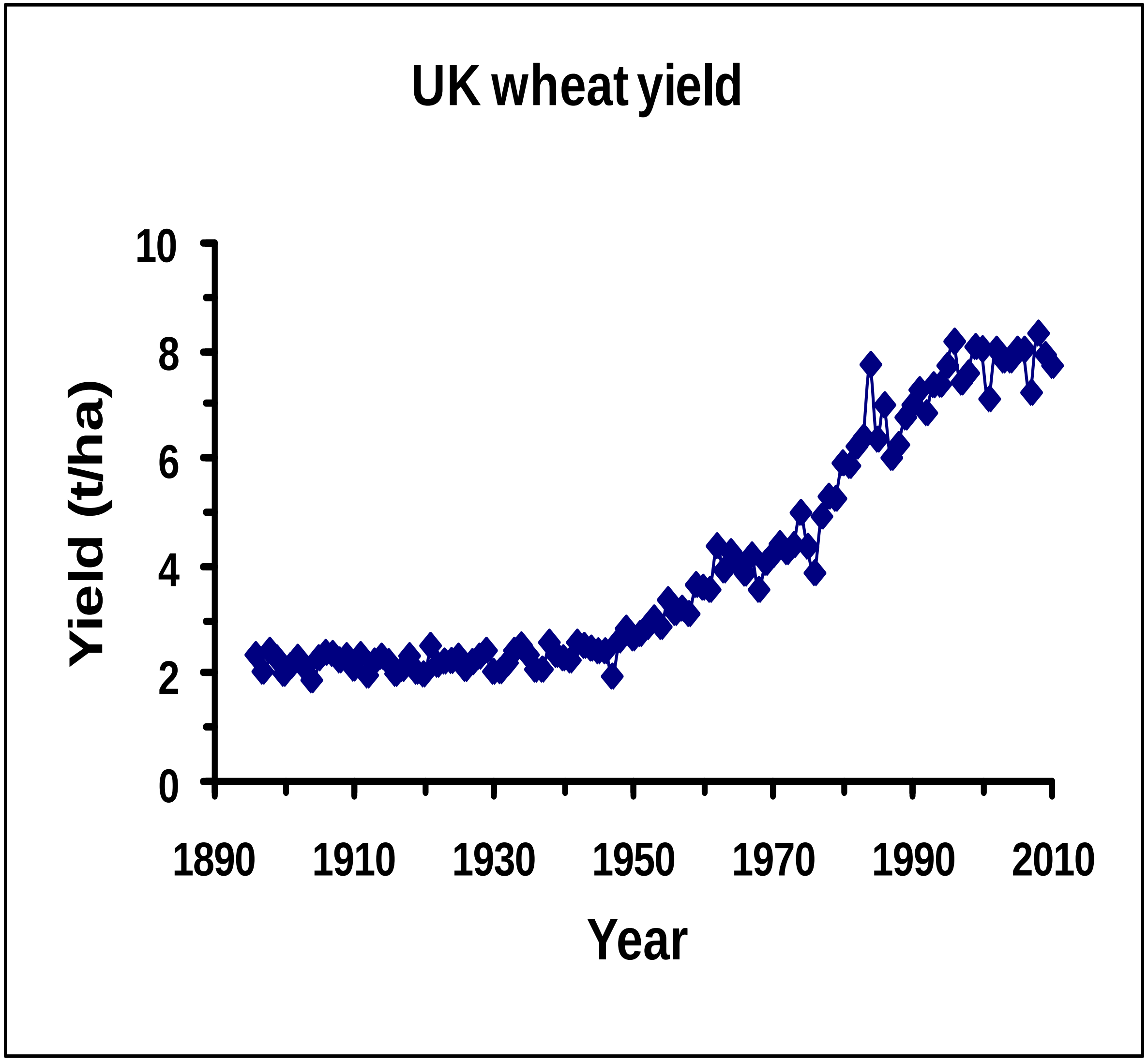
Stagnation of Yield Progress in Cereals?



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20:20 Wheat®

Delivering 20 tonnes/ha wheat in 20 years or less

20 years or less

The research requires:

- Long term strategic programme
- Range of disciplines
- Integrated approaches

Major challenges:

- Increase yield potential whilst maintaining quality
- Minimise gap between yield potential & actual farmers yield
- Maximise efficiency of input use for sustainability

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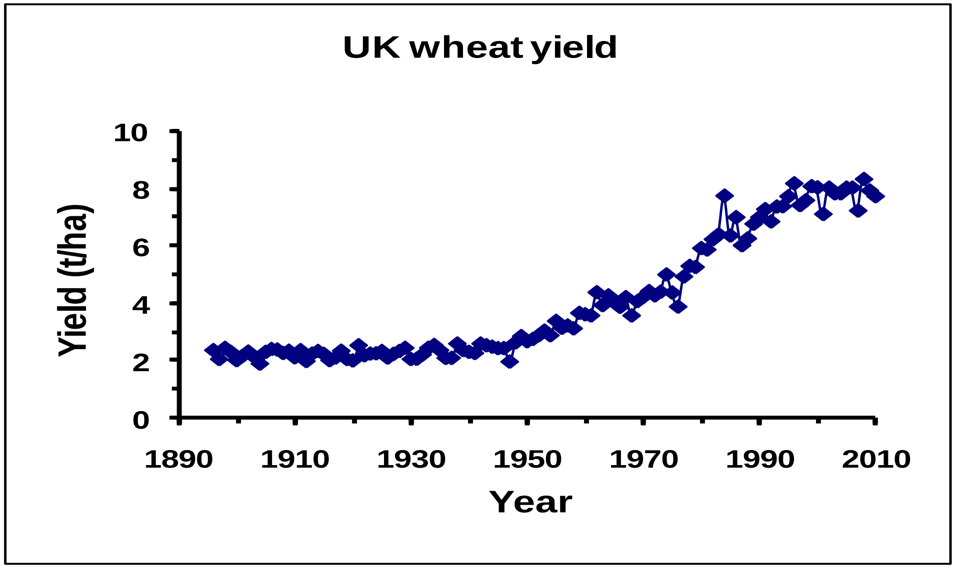
20:20 Wheat®

Delivering 20 tonnes/ha wheat in 20 years or less

Premise

Current average yield in UK is 8.6 tonnes/ha. World average is about 2.5 tonnes/ha. World food security will require a major increase in yields in the next 40 years



Improvements will be delivered in partnership with plant breeders facilitated by the Defra WGIN and BBSRC Wheat Pre-Breeding programmes

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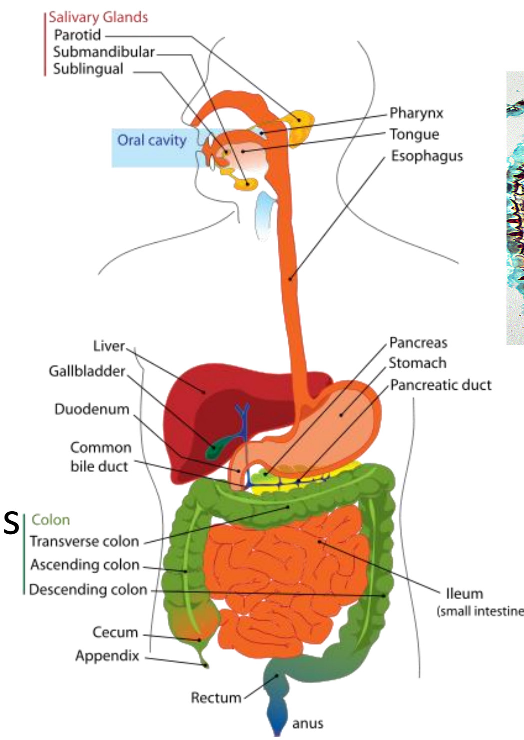
Designing Seeds

Delivering health and wellness though seeds

Premise

A high proportion of the human diet begins with seeds. By improving seed composition we can contribute to health and preventative medicine.

- Omega-3 fatty acids
- Complex carbohydrates
- Antioxidants



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Cropping Carbon

Improving the Carbon footprint of agriculture while contributing to energy security

Premise

The UK (and the world) is moving into a carbon economy. Agriculture can play a major role in mitigation of GHG emissions, also contribute to carbon sequestration and renewable energy strategies.

Willow

Miscanthus

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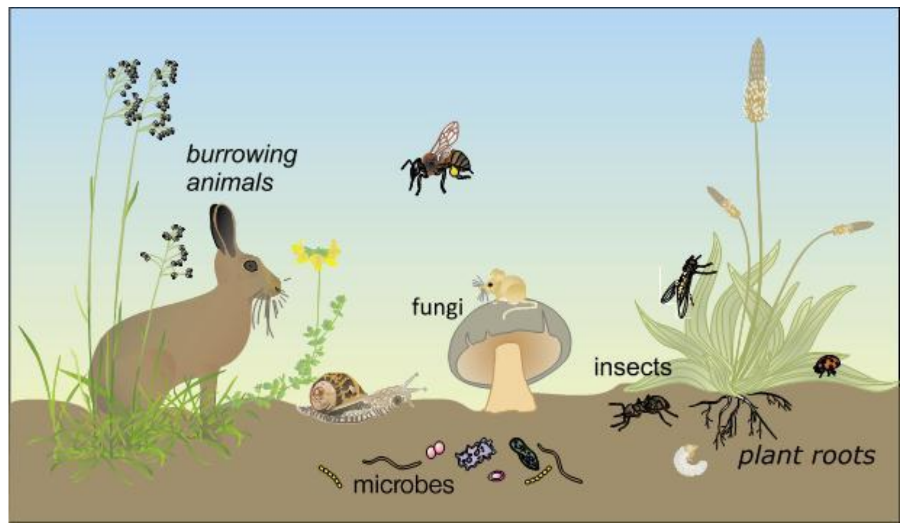
Sustainable Systems

Environmental and economic sustainability while maintaining yield and crop quality

Premise

Although there is a pressing need for increases in crop productivity this must ultimately be achieved with optimum environmental impact and with input-output economics that make sense for the farmer



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Rothamsted Research Science Strategy

20:20 Wheat
Increasing wheat productivity to yield 20 tonnes per hectare in 20 years
Martin Parry

Cropping Carbon
Addressing ways in which agriculture can assist in mitigating our carbon footprint and providing sustainable bioenergy
Angela Karp

Delivering Sustainable Systems
Designing, modeling and testing novel agricultural systems, which enhance sustainability while favouring high productivity with constrained availability of arable land
Keith Goulding

Designing Seeds
Harnessing our scientific strength in seed biology and biochemistry to deliver health and good nutrition through seeds
Johnathan Napier

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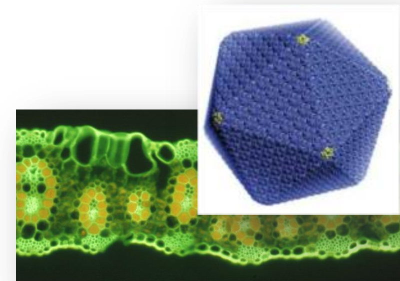
Rothamsted is uniquely multidisciplinary







From Field → **To Lab** → **To Field**

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Major Collaborations

UK

WISP	Bristol
JIC	Nottingham
NIAB	Lancaster
	Sussex
	Exeter

International

G20 Wheat Initiative
Wheat Yield Consortium
CIMMYT/ICARDA
CSIRO Canberra
EMBRAPA Brazil
USDA USA
CAS/CAAS/CAU China
India

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20:20 Wheat®

Delivering 20 tonnes/ha wheat in 20 years or less

The 20:20 wheat project aims to provide the knowledge base and tools to increase potential wheat yields (in the UK) to **20 t.ha^{-1}** within the next **20 years**

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20:20 Wheat®

Delivering 20 tonnes/ha wheat in 20 years or less

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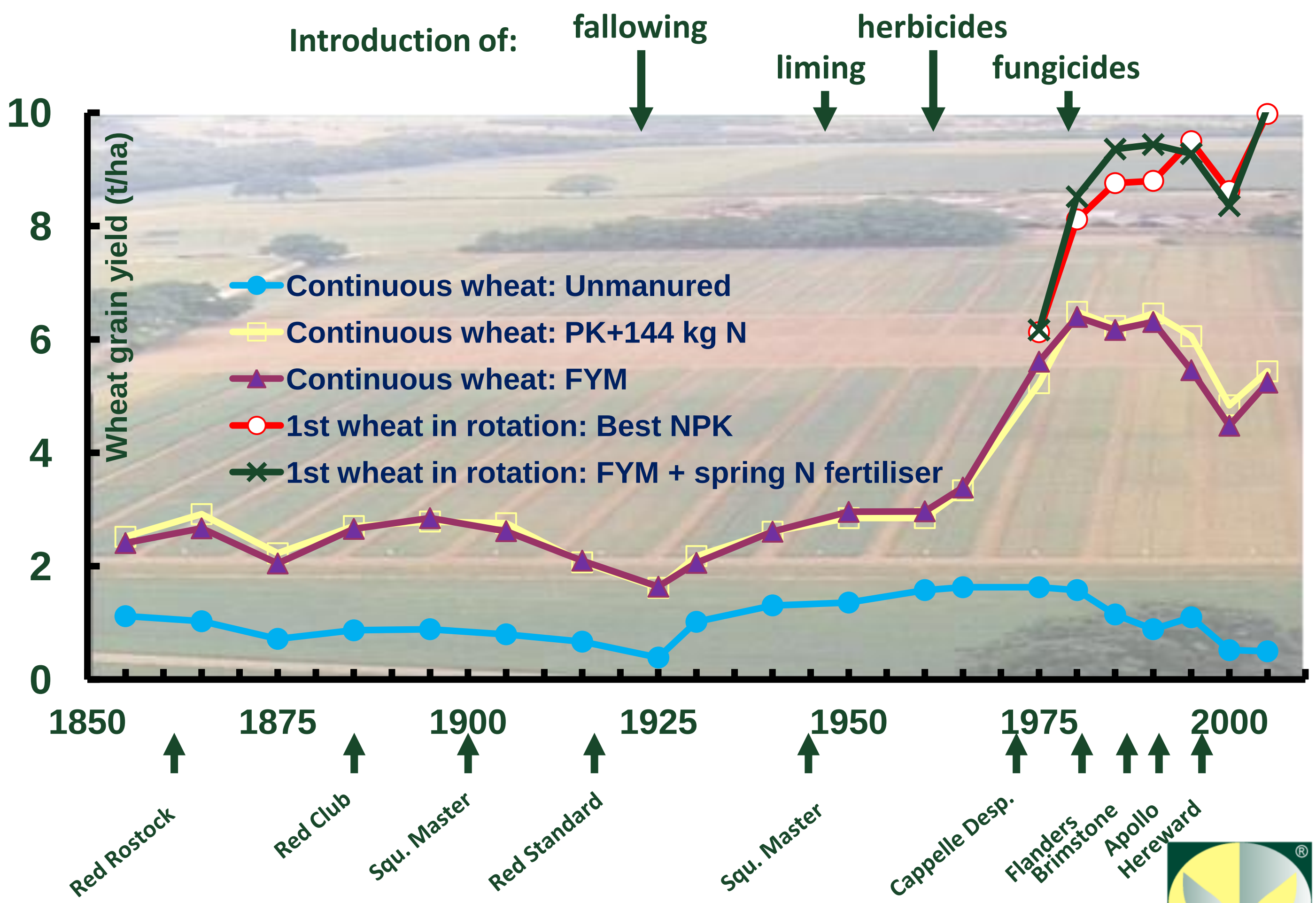
Long term Studies: Broadbalk 168 years of continuous wheat experimentation



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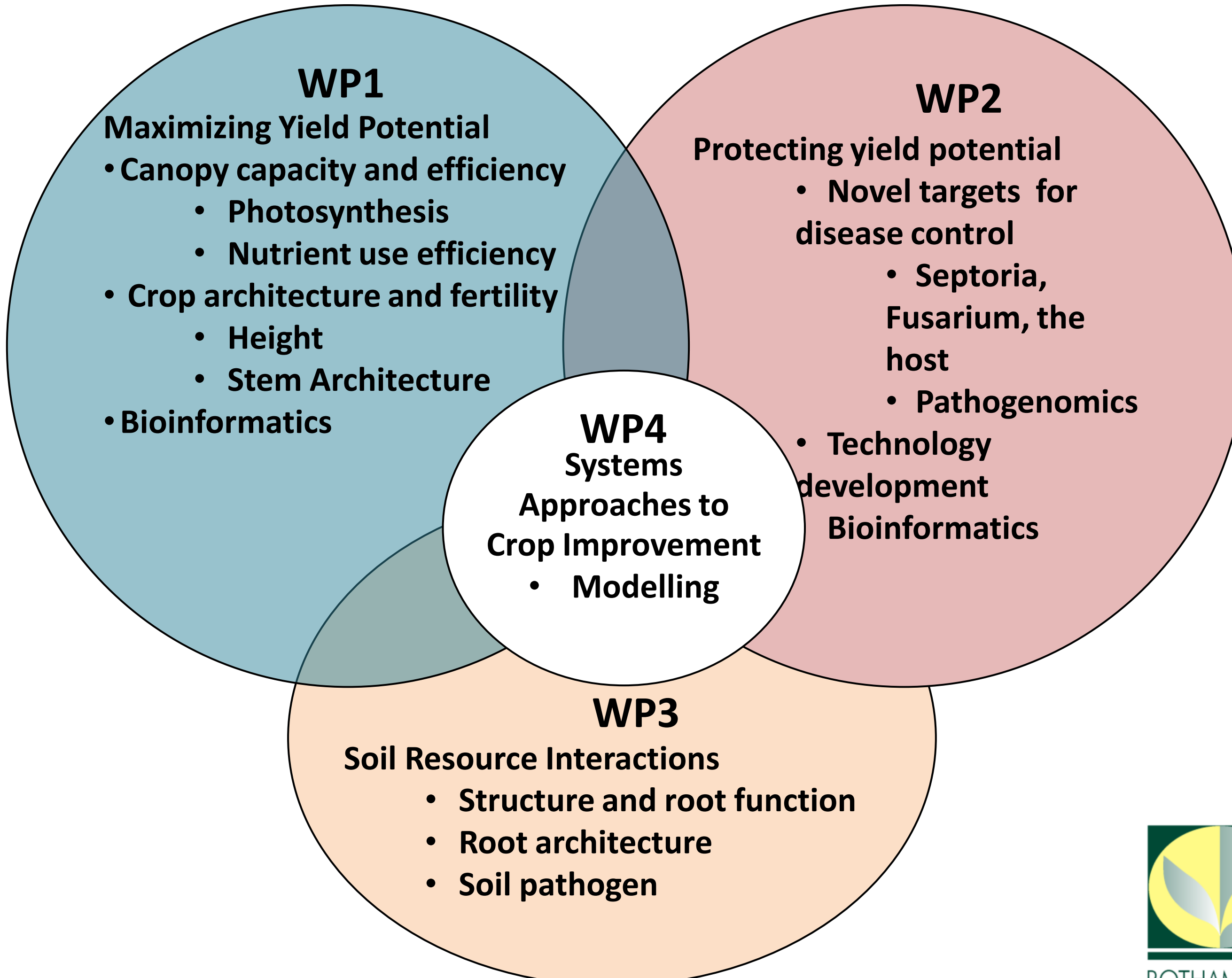
Research Clusters



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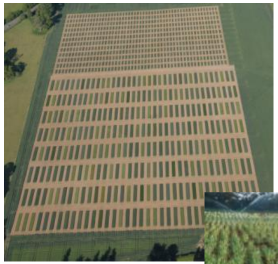
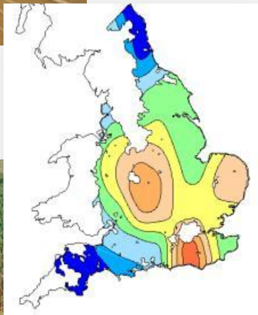
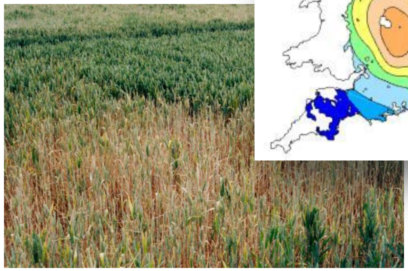
Key Objectives

- Exploit variation and biotechnology to increase biomass (NUE & photosynthesis).
- Enhance yield components by manipulating traits under hormonal control.
- Identify fungal genes whose function is necessary for wheat leaf infection.
- Define the signalling networks controlling Fusarium pathogenicity and mycotoxin production.
- Develop an understanding of how soil properties and root characteristics interact and constrain yield.
- Develop a modelling framework to predict performance of wheat ideotypes and traits.







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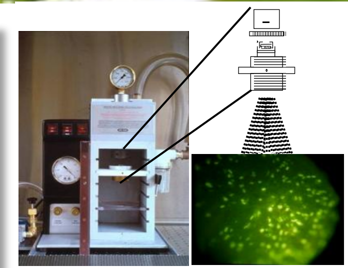
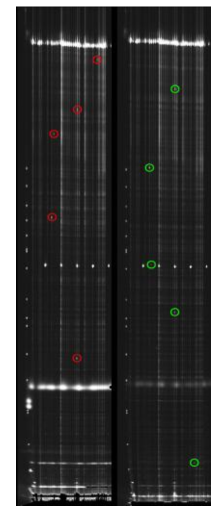
Enabling Technologies

- Transformation
    - 30 genotypes; 600++ independent lines p.a.
    - Field trials
- TILLING
    - Saturated EMS populations (4x and 6x wheat)
    - Forward screens: yield, yield stability, Hessan fly
    - Reverse genetics: mutants in GA signalling, quality, root or canopy architecture
- VIGS
    - Transient gene silencing and protein expression throughout wheat plants
- ‘omics’
    - NMR fingerprinting
    - Genomic data
- Bioinformatics
    - Crop store
    - Sirius, Ondex
    - Ppets
- Field phenotyping
    - High throughput plant phenomics
    - Measure & map water stress/soil strength

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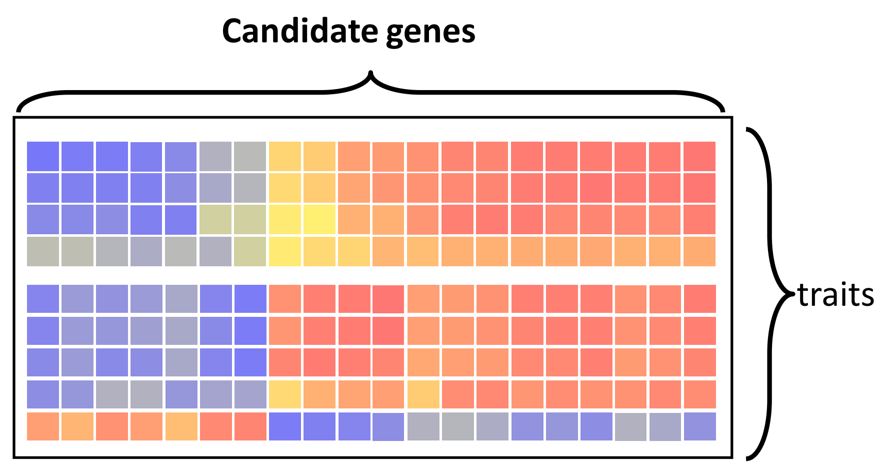
Identifying candidate genes

- Trait de-convolution and prioritization
- Assessment of variation
  - Provision of data for breeding
  - Aid new gene discovery
- Identification of genes/markers
  - Transcriptomics
  - Metabolomics
  - Bioinformatics
  - Correlation with traits
  - Mapping populations
- Breeding or biotechnology



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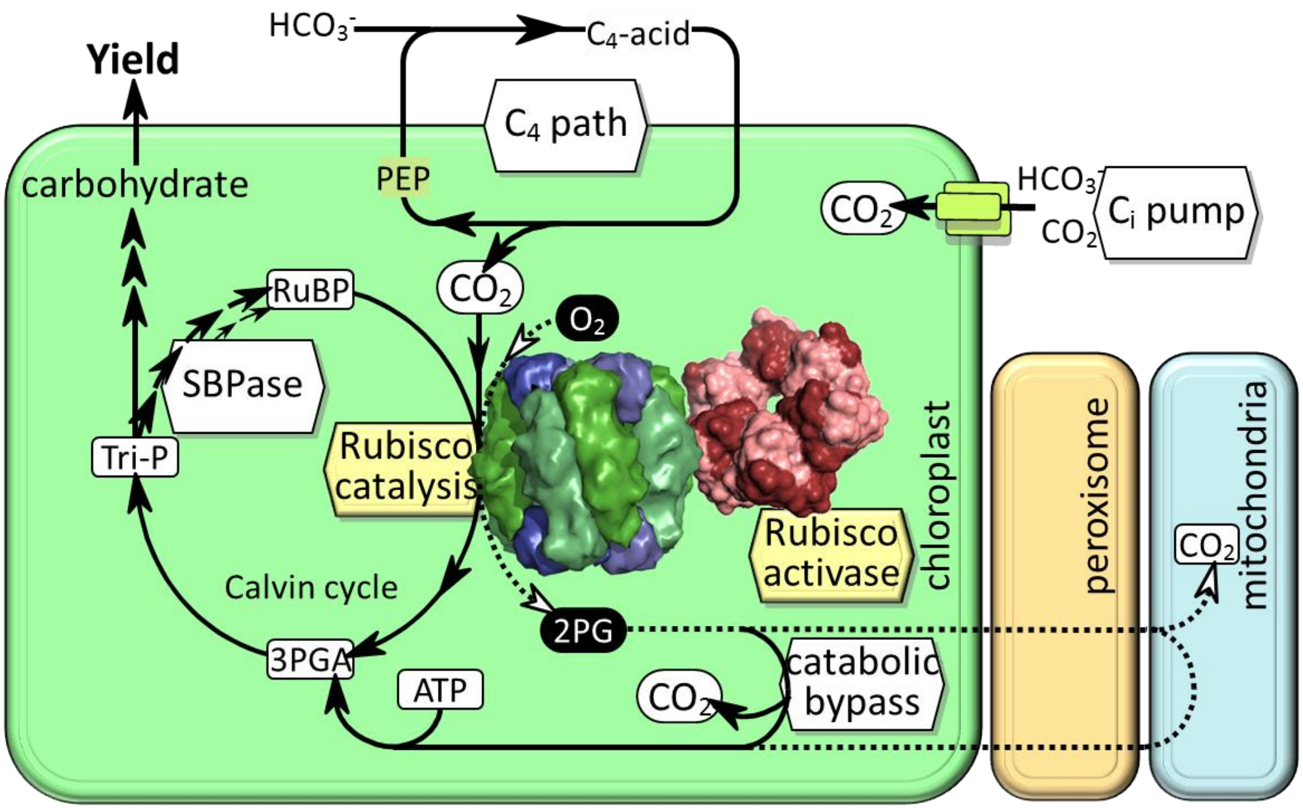
Overcoming photosynthetic inefficiency



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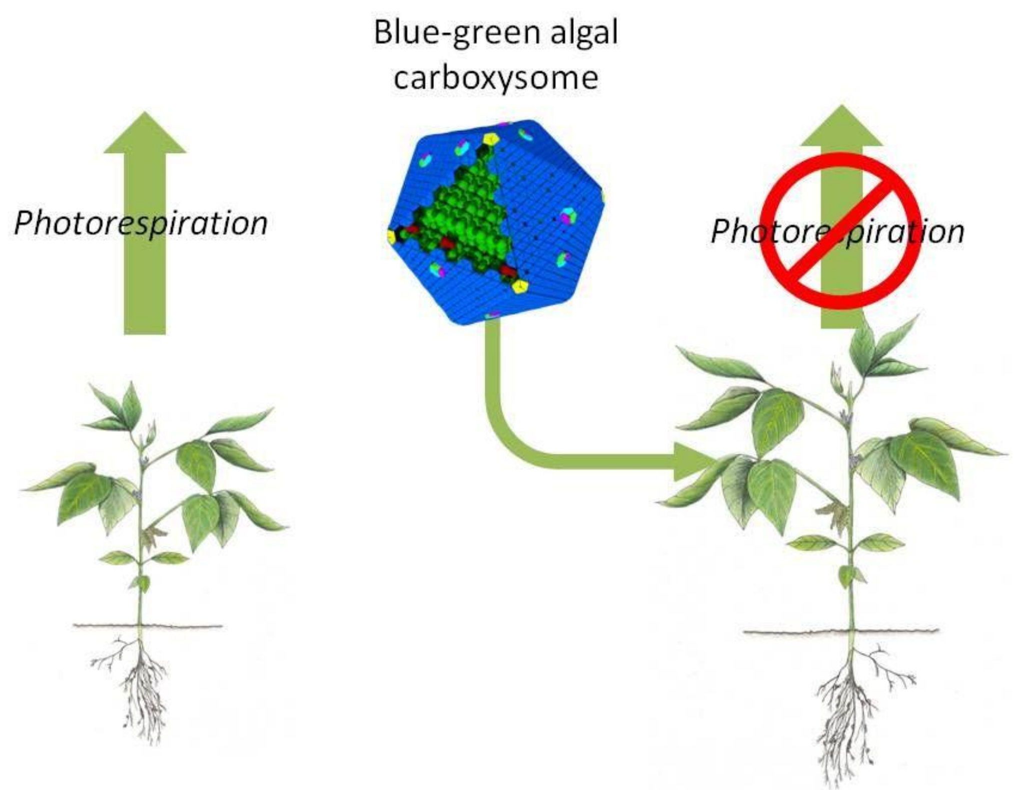
Case Study: EPP



EPP - Exploiting Prokaryotic Proteins to Improve Plant Photosynthesis Efficiency

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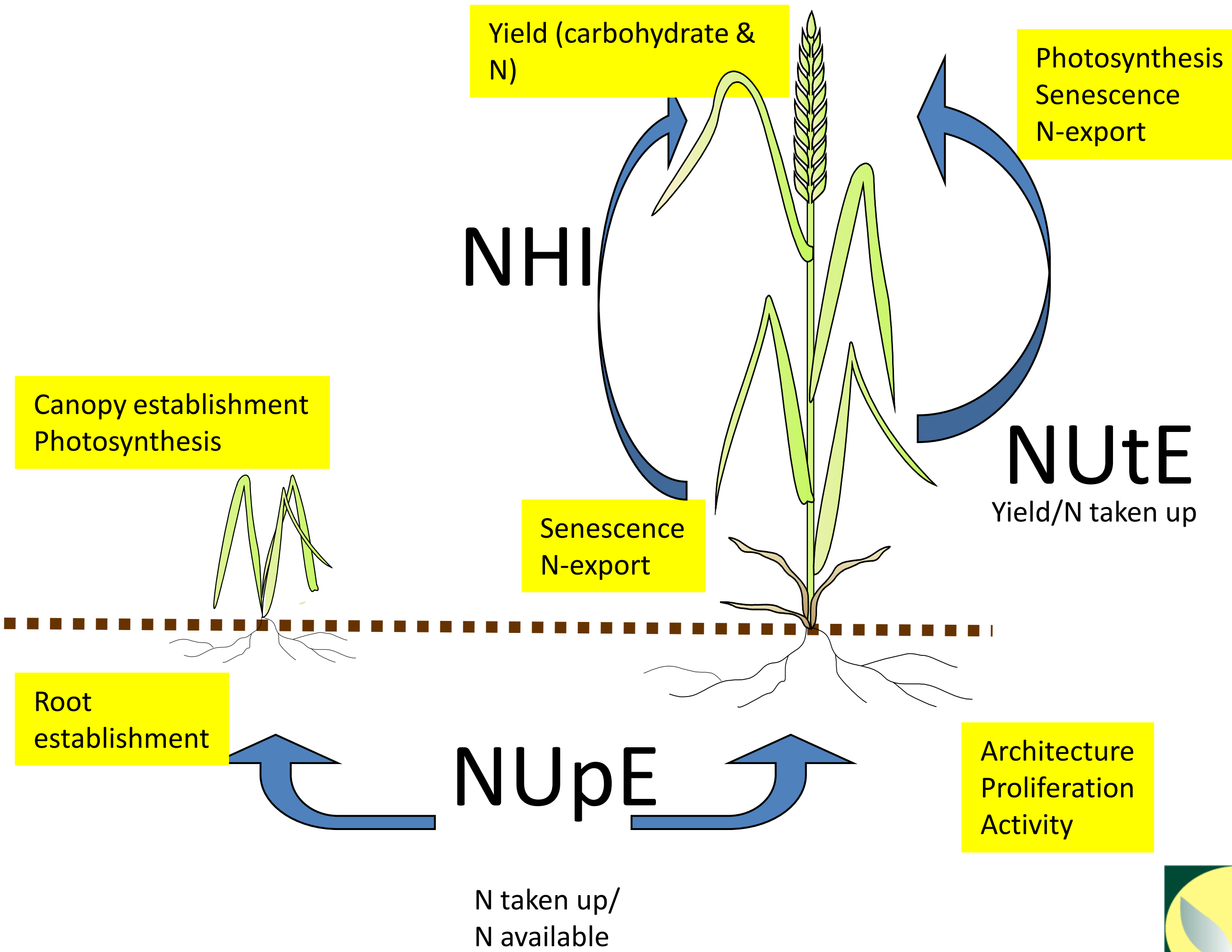
Efficient Nitrogen Use



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Crop architecture and fertility

Crop height is a major determinant of wheat yield:

• Tall plants are susceptible to lodging
…but reduced height often associated with reduced biomass & yield

• Introduction of Rht semi-dwarfing genes (Green Revolution) retained high yield on lower biomass by reducing GA sensitivity

…but Rht also has some negative pleiotropic effects eg. reduced grain size, impaired fertility

• Manipulate novel targets in GA pathway to increase specificity.

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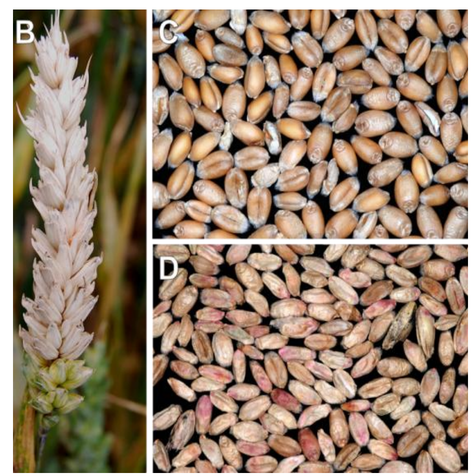
Protecting Yield Potential

Septoria

Fusarium + mycotoxins



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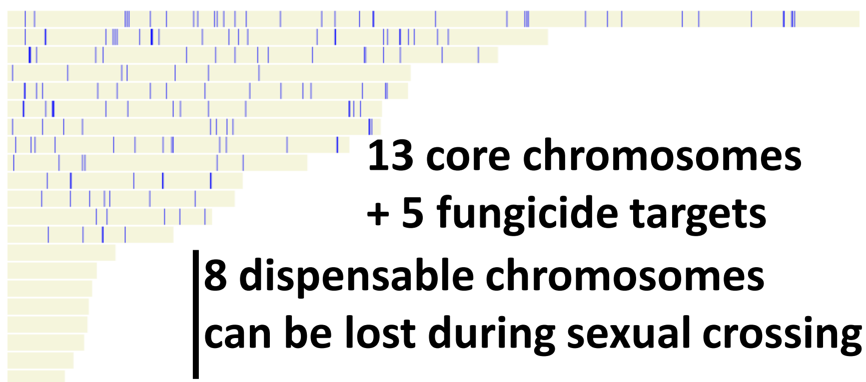
Pathogen Attack and Genome Analyses

Septoria tritici

39.7 Mb – 10,933 genes

21 chromosomes



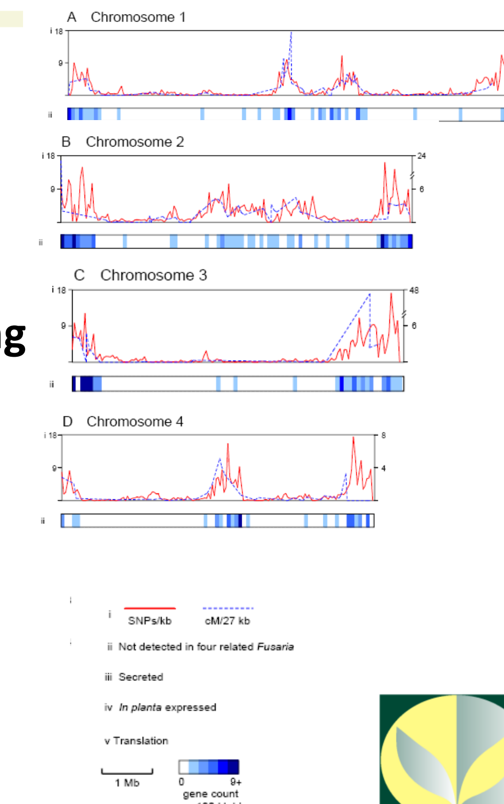
13 core chromosomes
+ 5 fungicide targets

8 dispensable chromosomes
can be lost during sexual crossing

(12% genome, 6% genes)

Fusarium graminearum

36 Mb – 13,718 genes



Evidence for ancient fusion of chromosomes where the greatest polymorphism between isolates is maintained

Focus : Identification of novel targets for interventions

***F. culmorum* – 39 Mb (2010)**

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Soil Resource Interactions

2^{nd} wheat syndrome:
a major problem
for 2^{nd} / 3^{rd} wheat crops

Typical take-all patch showing
stunting & premature ripening
of the crop

The risk of take-all is largely dependent on the amount of inoculum in the soil at the time of sowing

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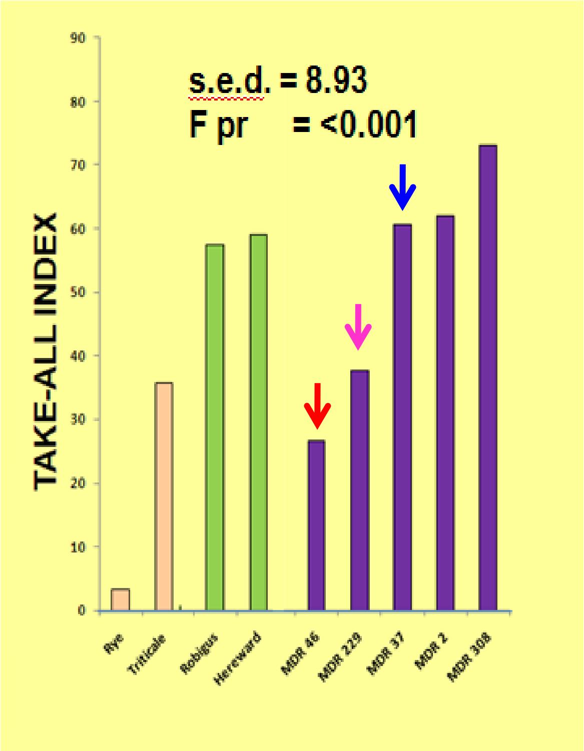
Soil Resource Interactions

Some *Triticum monococcum* (AA genome) accessions exhibit good tissue based ROOT RESISTANCE to take-all infection in replicated pot and field tests over 5 years (5 resistant accessions from ~120 screened)



2009 field data – 10 rep plots per line

FIRST IDENTIFICATION OF TAKE-ALL RESISTANCE IN A *Triticum* SPECIES

MDR037 x MDR046
MDR037 x MDR229

→ Harvest F_4 Feb 2011 onwards

↓

Take-all pot test (~30 seed / line)

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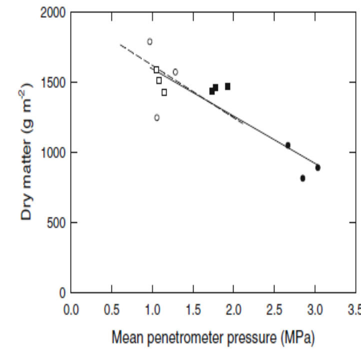
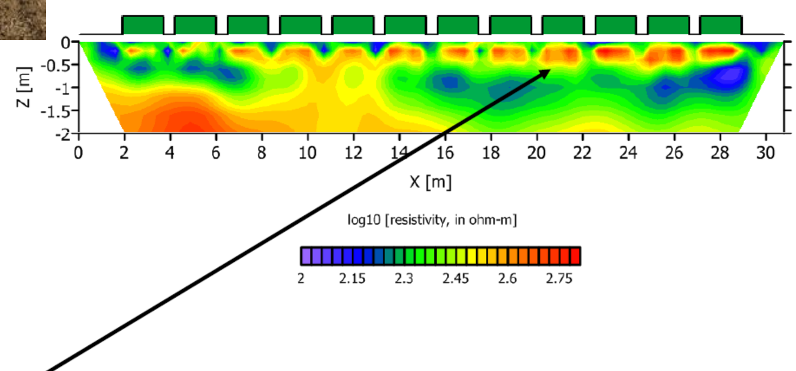
Soil Resource Interactions

Selecting germplasm that can penetrate "strong soils" using hydrotomography



Non-irrigated

Absolute inversion 13-May-11



Appears to show significantly reduced water content down to 0.5m, especially in the plots towards the end of the line.

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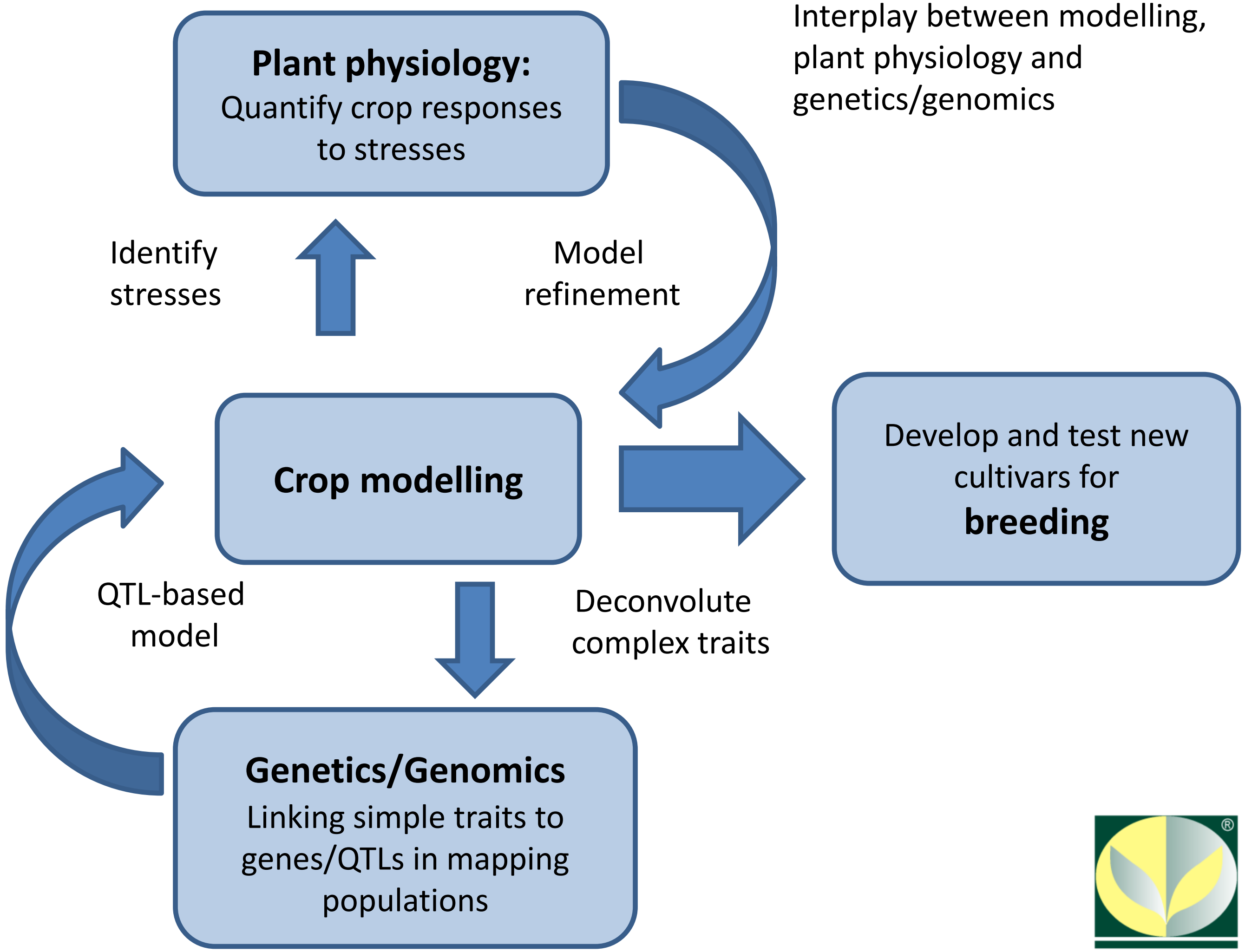
Systems Approaches to Crop Improvement

Interplay between modelling, plant physiology and genetics/genomics



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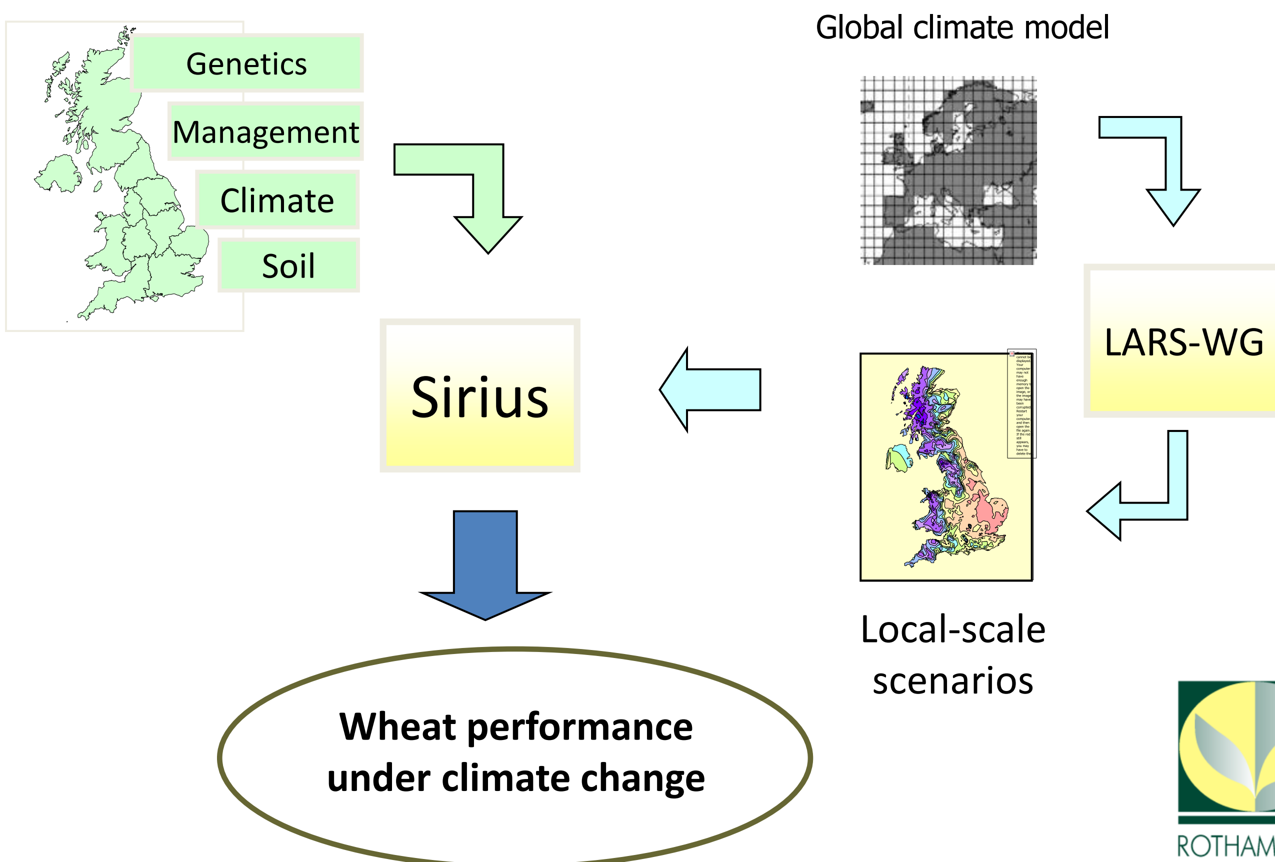
Modelling crop performance in target environments

- Explore stability of GxE relationships for new ideotypes
- Deconvolute complex wheat traits including traits for resource-use efficiency
- Design wheat ideotypes for a changing climate



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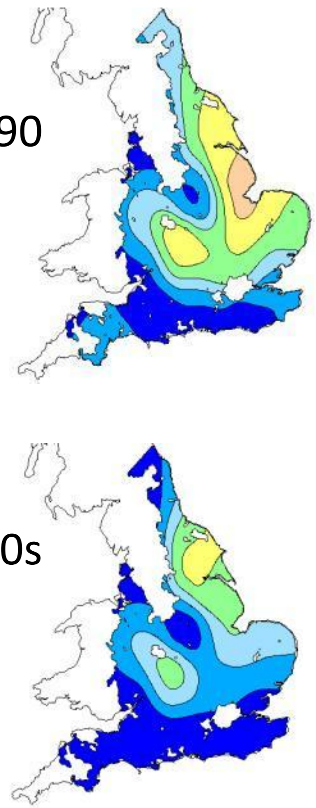
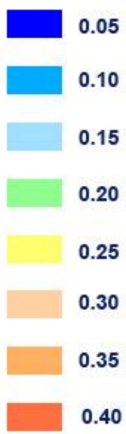
Modelling predicts that heat stress, not drought, will increase vulnerability of wheat in the UK

Yield losses due to water-stress decreased

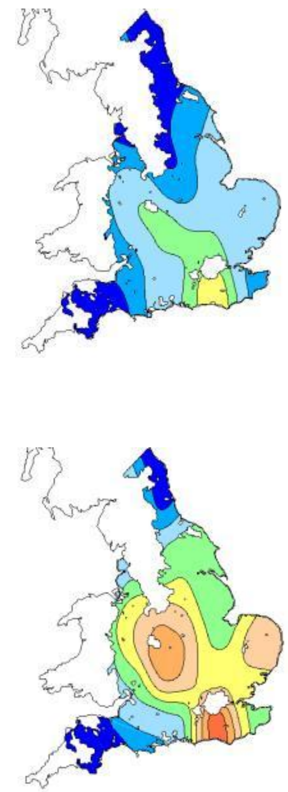
1960-1990

2050s





Probability of heat stress at flowering increased resulting in yield losses



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Potential Value

- For the UK
  - every 1 $t.ha^{-1}$ increase in yield is worth £318M p.a. at the farm gate
  - A 20% improvement in NUE is worth £68M p.a.
  - 2nd/3rd wheat yield penalty of 1-5 $t.ha^{-1}$from Take-all disease
  - Up to £700M yield loss from Septoria and 12% crop loss from Fusarium mycotoxin contamination

    (One less fungicide spray per season on every wheat field –

    improved chemical efficacy / longevity, better use of Ind R & D)

- Global
  - Enormous impact on both developed and developing countries

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Conclusion

Food Security is a global problem and cannot be solved by any one Institute alone

Rothamsted Research is building strategic links and scientific collaboration with key players internationally to find solutions to food security through sustainable agriculture

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