

# Commercial Wheat Breeding: Challenges and Research Opportunities

WGIN 25 November 2009



# Wheat Breeding: Challenges and Research Opportunities

- Commercial breeder involvement with setting research agenda
- Public/private partnerships
- Efficient marker/genomics platforms
- QTL dissection and association genetic studies
- Genes with selectable marker, no linkage drag, no pleiotropic effect in stable hexaploid background
- Accelerated breeding methodology



# Wheat Breeding: Challenges and Research Opportunities

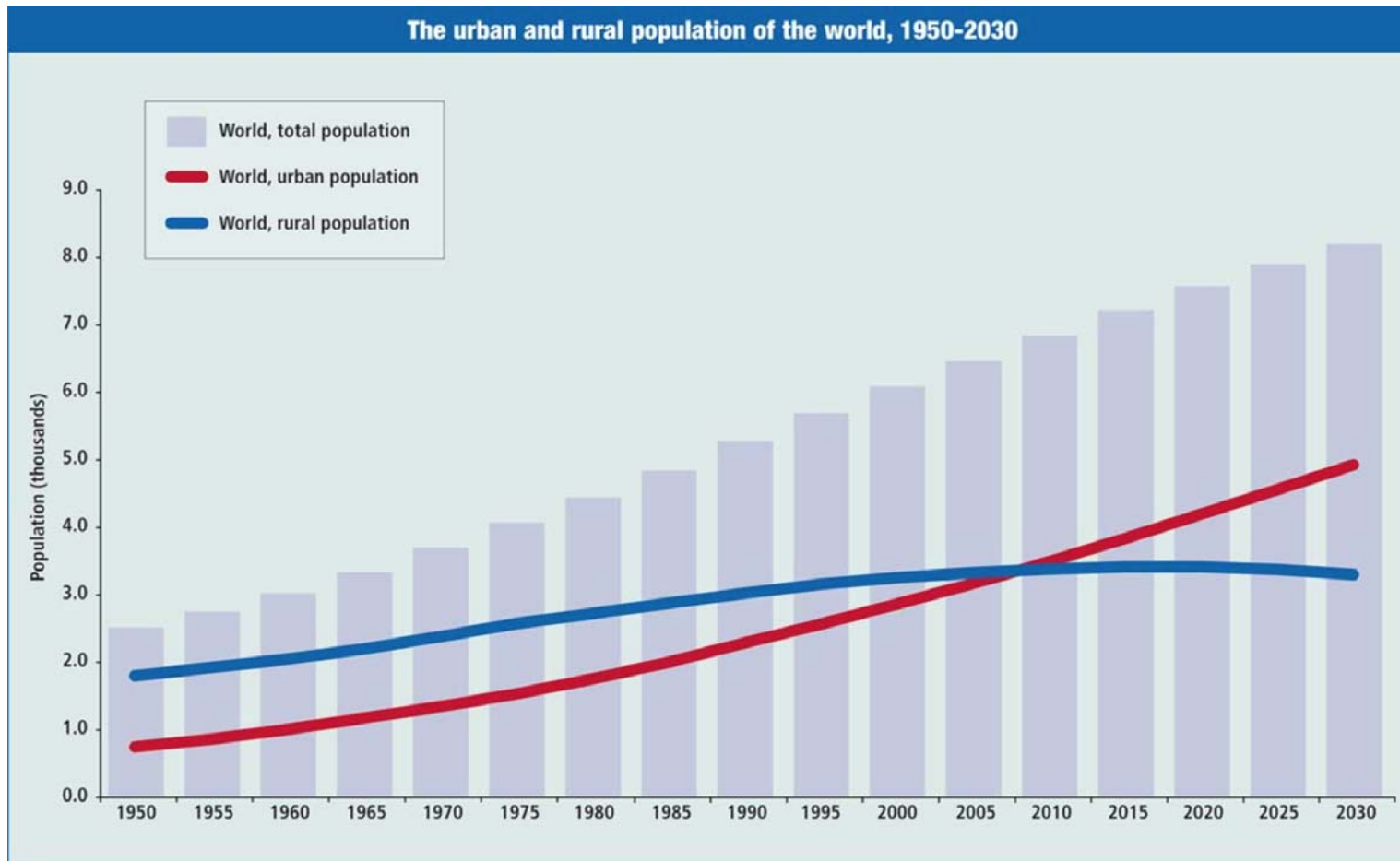
- **Global population growth**
  - Increased production required (+50% by 2030)
- **Climate change**
  - Increased focus on temperate zone agriculture
- **Pressure on limited resources**
  - Land, energy, water, fertiliser, pesticides
- **Improved productivity essential**
  - Plant Science  $\leftrightarrow$  Plant Breeding



Courtesy of BSPB



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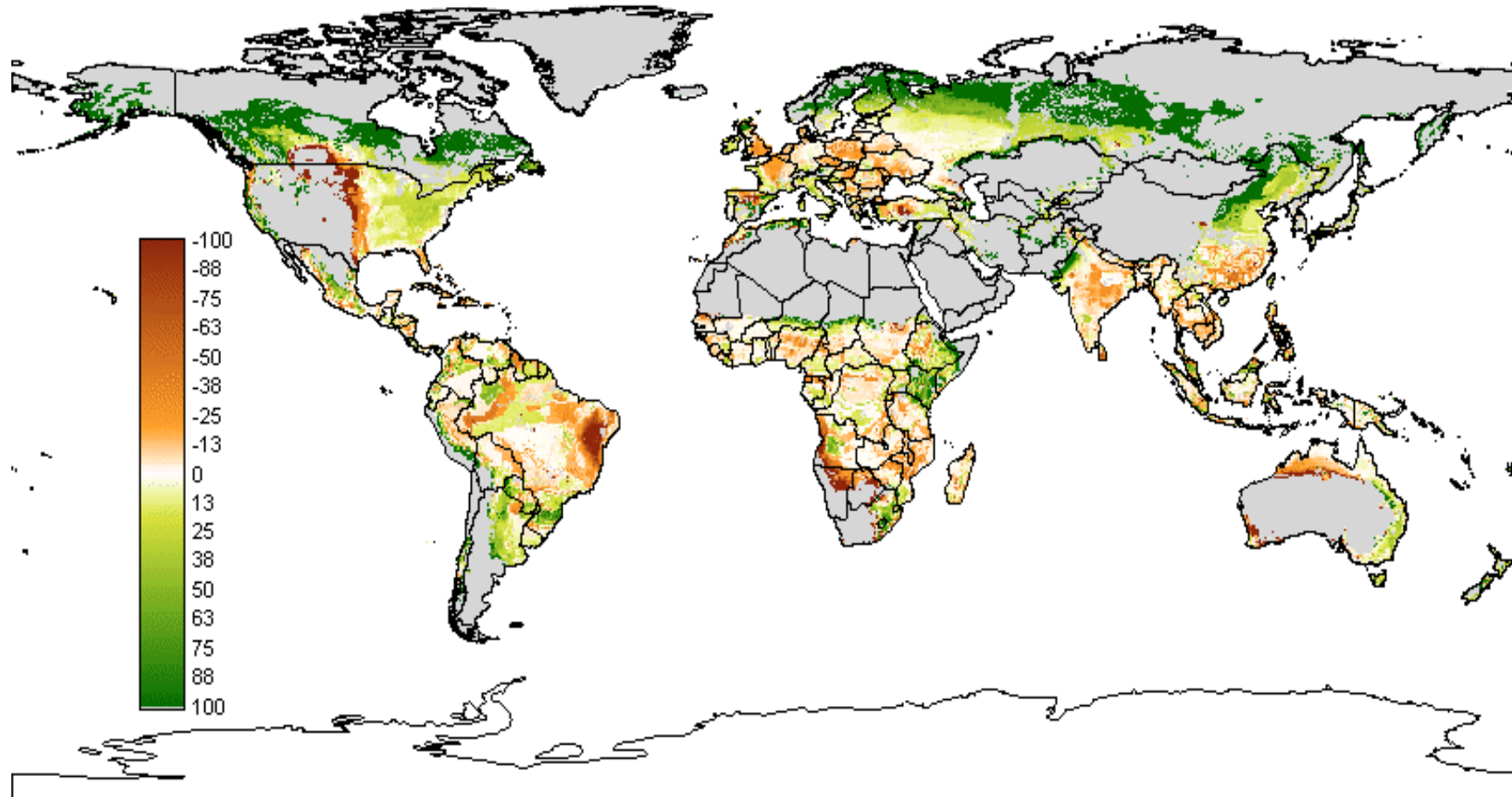


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# Wheat Breeding: Challenges and Research Opportunities

Climate Change  
World Cereal Production 2050 (ISIA)

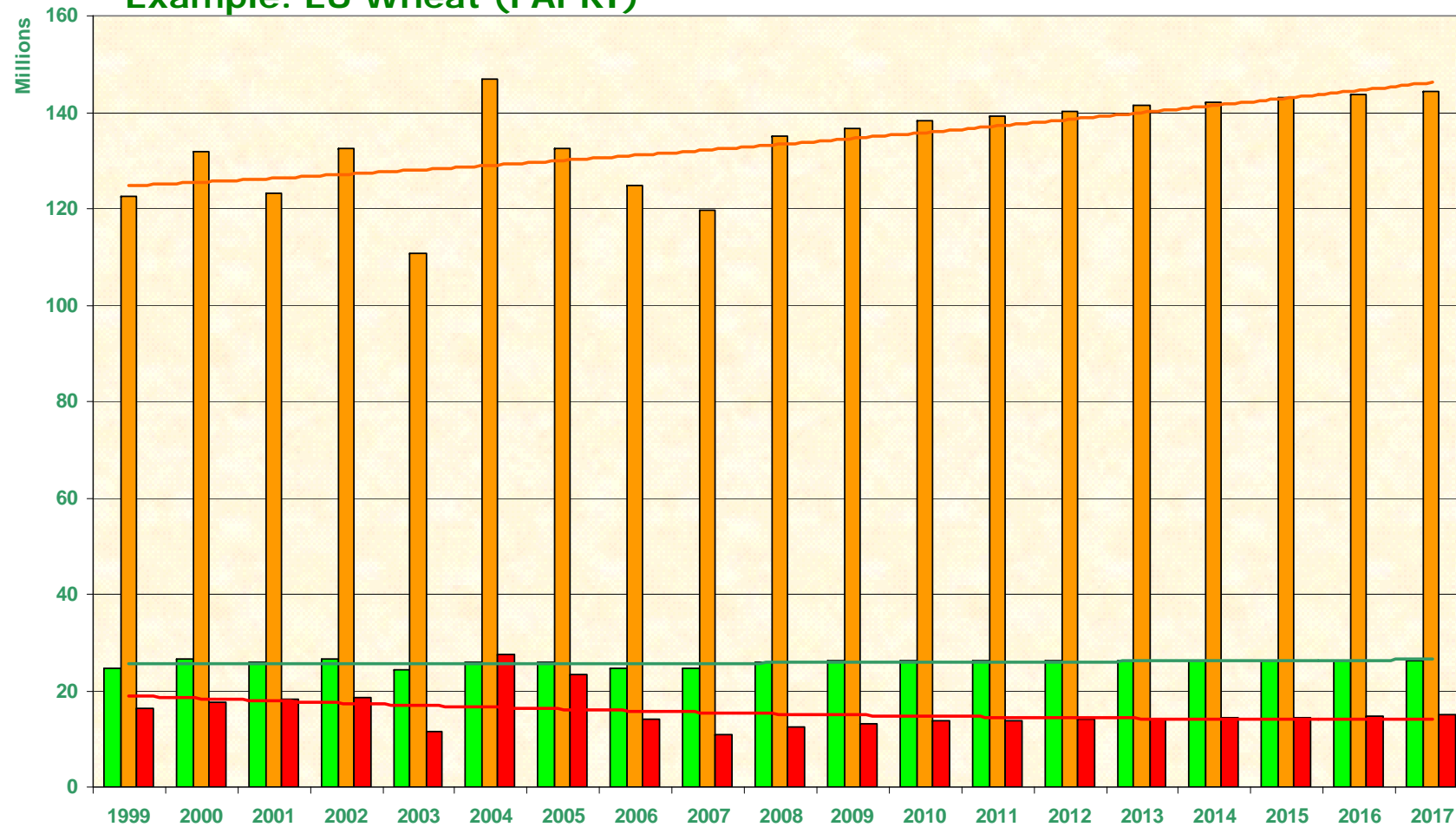


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# Wheat Breeding: Challenges and Research Opportunities

World Demand for Commodities  
Example: EU Wheat (FAPRI)



■ Crop Area (ha) ■ Production (t) ■ End Stock (t)

Courtesy of BSPB



# Wheat Breeding: Challenges and Research Opportunities

- Stricter nitrate regulations
  - Extension of NVZ
  - Revision of RB209
- Restriction in licensing and application of pesticides
  - Political, EU and UK
  - High Court, Georgina Downs
- Grain assurance, mycotoxin appraisal
- DEFRA biodiversity targets
  - To reverse decline in farmland birds by 2020



Courtesy of Bingham



# Wheat Breeding: Challenges and Research Opportunities

## Hilary Benn on science funding and plant breeding:

“Defra provides £68 million a year in research funding, the BBSRC £70m a year, the AHDB £20m and industry and NGO contributions to LINK research about £6m – making a grand total of £164 million a year.”

“Our priorities are animal health and lessening harmful greenhouse gases and water pollution..., **as well as looking at ways of adapting to climate change where plant breeding – including new varieties – will be very important.**”

“Have we got our priorities right? Are we and the industry, including the AHDB and the food processors, investing enough? Are we good enough at applying the knowledge and the science we already have?”

Oxford Farming Conference, Jan '09



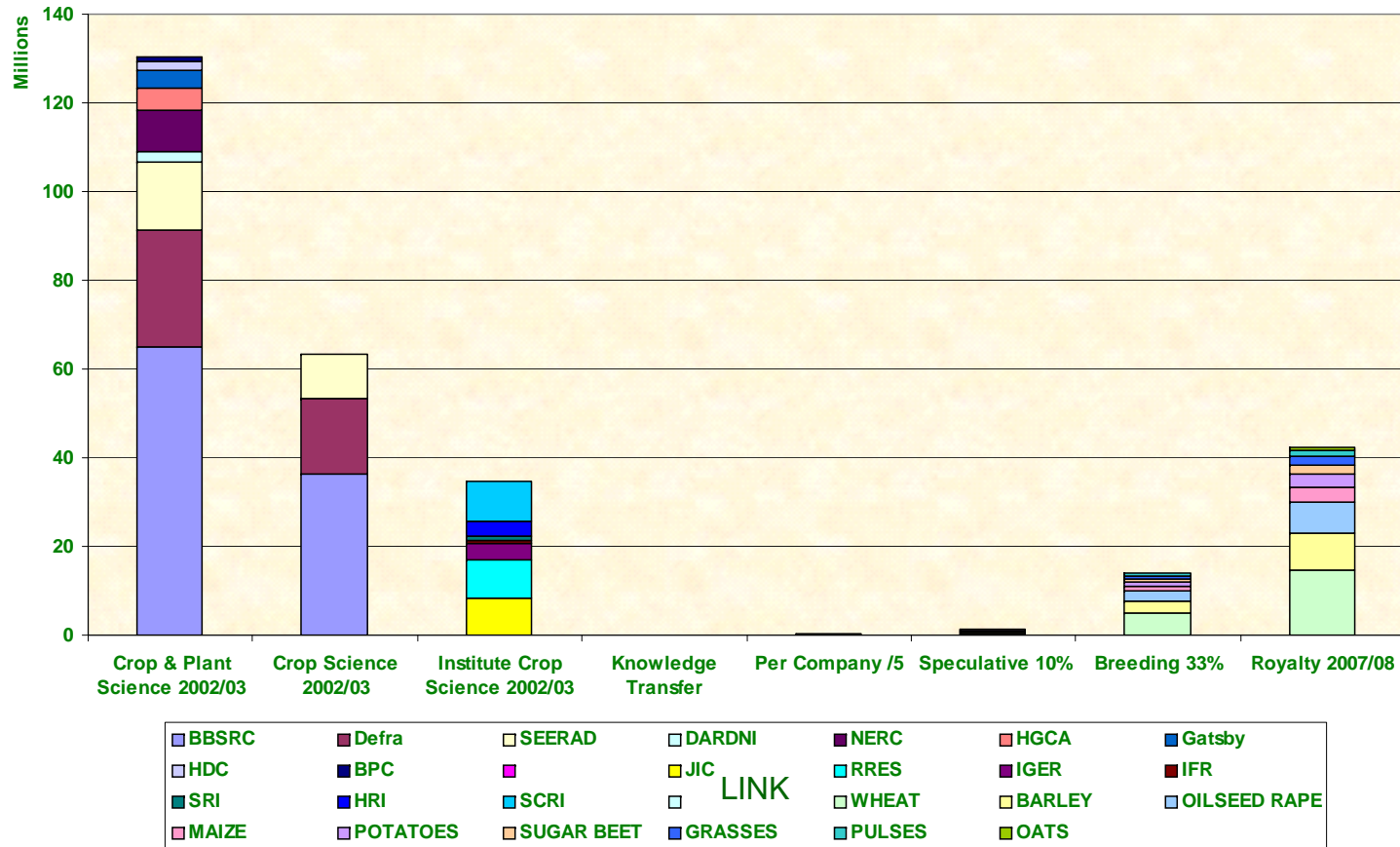


# Wheat Breeding: Challenges and Research Opportunities

- Royal Society report
- Crop Improvement Club
- TSB investment plus KTN's
  - Sustainable agriculture call including crop protection
- Pre-breeding initiatives and new LOLA's
  - e.g. wheat genetic improvement initiative submitted to BBSRC with full BSPB backing and involvement
- Chief Scientist initiatives



# Wheat Breeding: Challenges and Research Opportunities



Courtesy of BSPB



# Wheat Breeding: Challenges and Research Opportunities

- Bingham and Summers note to the Chief Scientist, 3 November 2009: UK Wheat Breeding, a “Model for the Application of Research in Plant Genetics, Yield, Disease Resistance and Grain Quality”
  - Wheat national average yields increased from 2.8 t/ha in 1948 to 8 t/ha today
  - NIAB analysis suggests between 1948 to 2007 57% of increase due to plant breeding (93% over the last 25 years)
  - Contribution of wheat breeding to production is in the order of £500M per annum, achieved by breeding research funded from an annual royalty income pot currently of £16M per annum



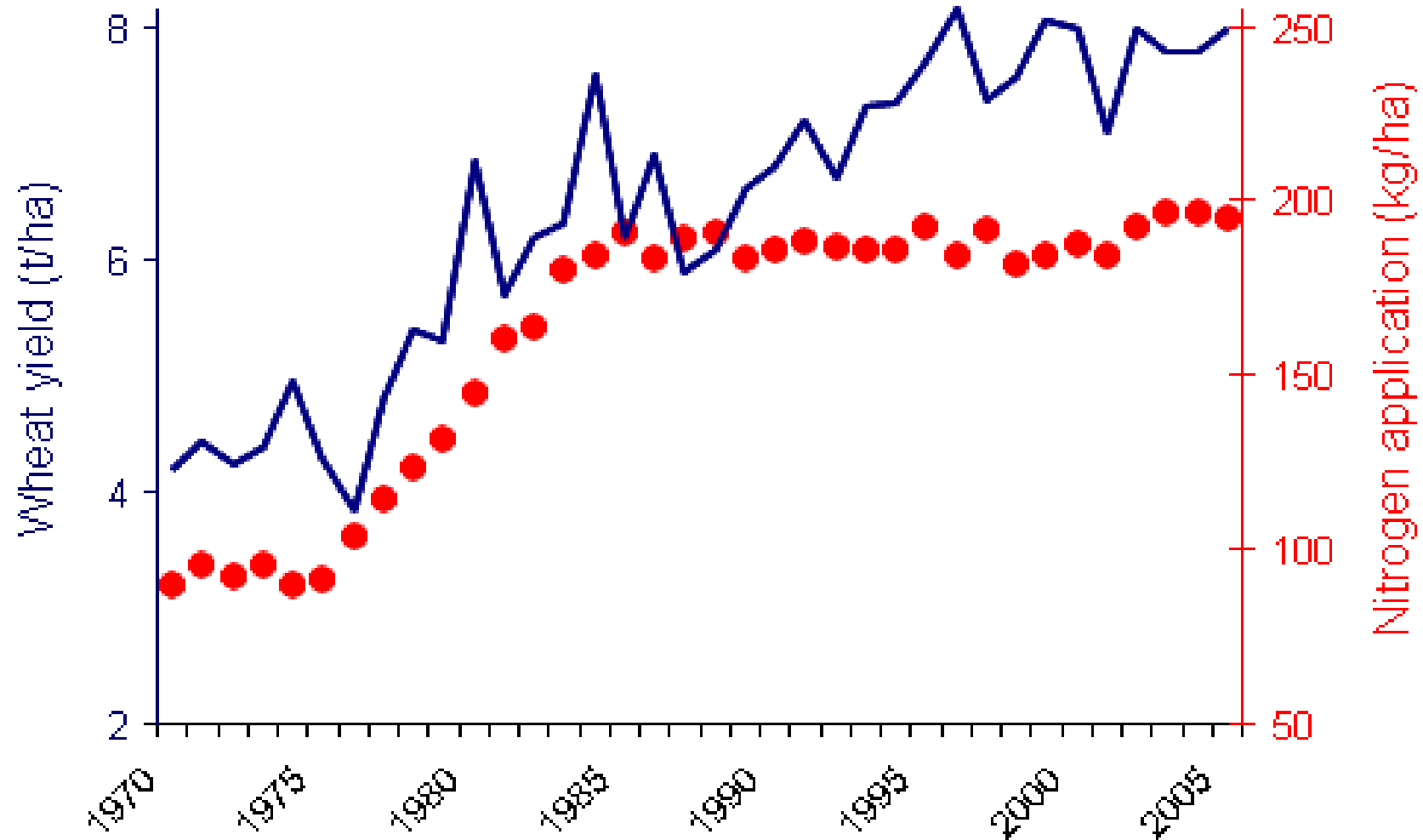
Courtesy of Bingham and Summers



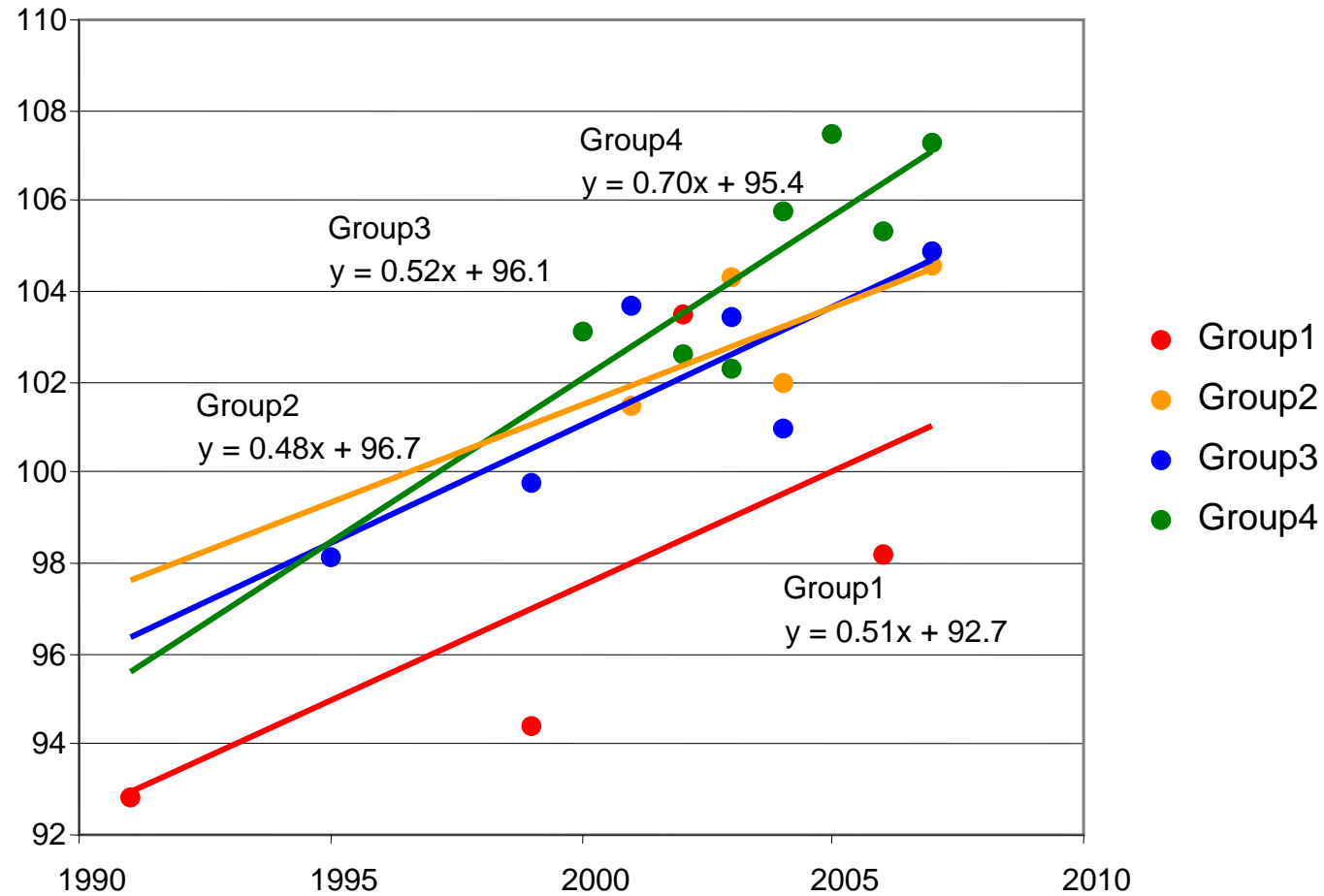
# Yield



# Yield & N fertiliser



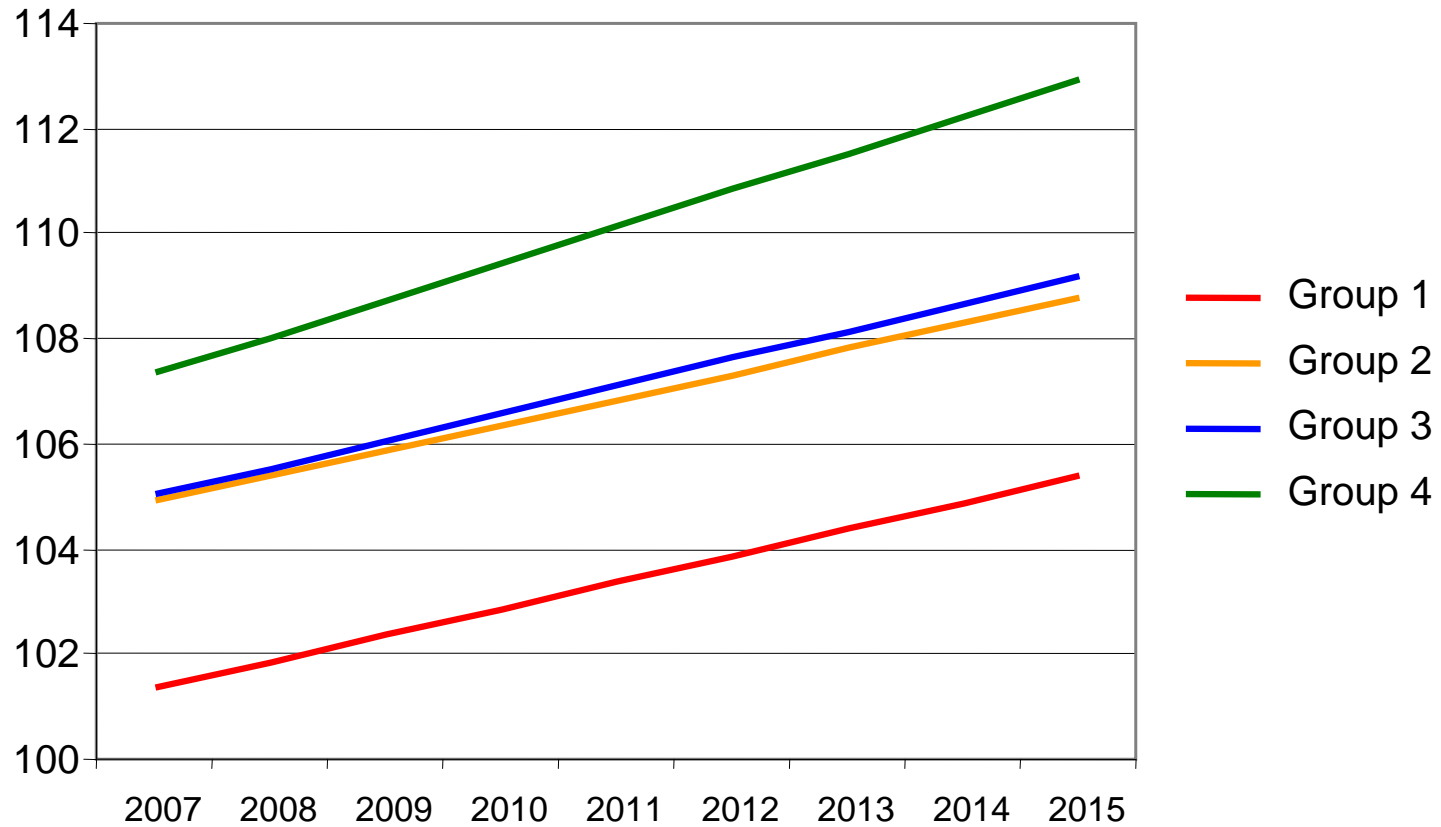
# RL Yield advance



Data extracted from HGCA/CEL Recommended Lists  
Courtesy of Flatman



# RL Yield projection



25% to 50% yield genetic gain by 2050?



Data extrapolated from HGCA/CEL Recommended Lists  
Courtesy of Flatman



# Wheat Breeding: Challenges and Research Opportunities

- As measured in Recommended List Trials, with standard agronomic practice, the yield potential of new varieties continues to advance by an average of more than 0.5% annually. However, national average on farm yields have stagnated, indicating a **need for an in depth agronomic investigation** to build on the RASE Soils Report.
- The current rate of progress in varietal yield can be maintained for some years by **extension of the current gene pool and more intensive use of genetic markers**. However, **there is no prospect of a stepwise increase in yield** equating to a second green revolution unless the physiology of the crop can be radically advanced.
- In this respect there is no certain way forward and a lack of accord, so high priority should be given to an **independently chaired discussion group** (GO Science?) able to bring together a range of research disciplines and challenge proposals.



Courtesy of Bingham and Summers





# Wheat Breeding: Challenges and Research Opportunities

- **The agenda for the group should be restricted to yield and include**
  - **A mainly genetic approach based on genomic analysis**, aiming to match in wheat the widely promulgated claim that maize yields will be doubled by 2030.
  - **Increased photosynthetic rate, essential to meeting 2050 yield targets for wheat.** The ideal route would be the intensively 'C4' system of maize and many other sub-tropical species; an update is needed on progress in transfer to rice. The intermediate C3/C4 system of Moricandia and some grass species may be more accessible. Either system would increase efficiency of water use. Some wild diploid (14 chromosome) relatives of hexaploid (42 chromosomes) wheat do have a higher rate of photosynthesis. A 1985 attempt to exploit this source was not successful but should be reconsidered.
  - **An in depth review of N fixing based on recent evidence from legumes.** Transfer to wheat is a major objective but would reduce yield, due to the energy requirements of N fixation, unless combined with increased photosynthetic rate.
  - **Value of heterosis.** Hybrid or apomictic breeding schemes could be of great value in fixing hybrid vigour.
  - **Genetic adaptation to moderate increases in temperature.** The widely based gene pool will enable breeders to meet 'moderate' changes in climate in the normal course of selection.



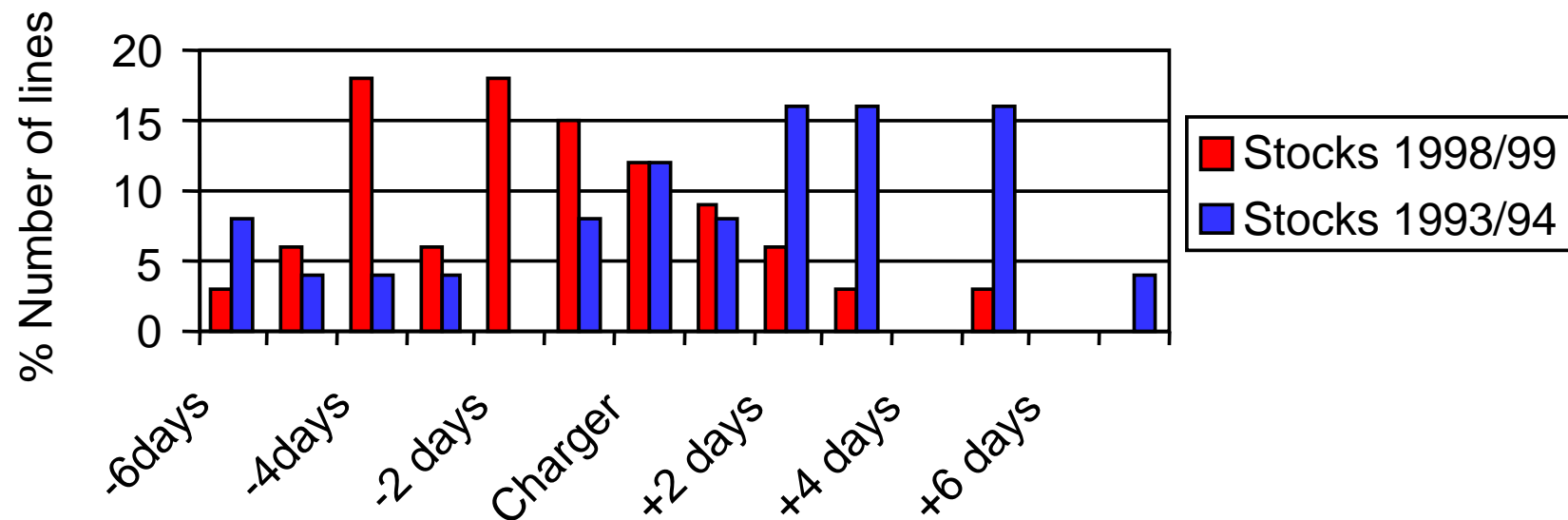
Courtesy of Bingham and Summers



# Adaptation



# French Programme: selection for earliness



Ear emergence relative to Charger  
expressed as % number of stocks per ear  
emergence class



# Frost damage Beauce site 2002/03





# Frost damage Beauce site 2002/03



# Disease and pest resistance



# Wheat Breeding: Challenges and Research Opportunities

- Disease and pest resistances are of high priority in the UK to minimise the need for chemicals, and in developing countries to increase both production and security of food.
- New virulent races of leaf diseases, e.g. yellow rust 2008-9, need to be solved by the **use of molecular markers to trace durable sources** of resistance in wheat and **find new derivatives in wild species**. Work will not be straight forward, previous attempts to exploit wild species since the 1950s having been foiled by new races or close genetic linkages to deficiencies in the physiology of yield.
- Other objectives should include resistance to **intransigent problems** take-all, Barley Yellow Dwarf Virus (BYDV), aphids and even slugs.
- Currently the most notable success from a private/ public sector partnership is in recommended varieties with resistance to wheat orange blossom midge, so avoiding the need for non-specific insecticides at ear emergence.



Courtesy of Bingham and Summers



# Sourcing useful genes





# Quality



# Wheat Breeding: Challenges and Research Opportunities

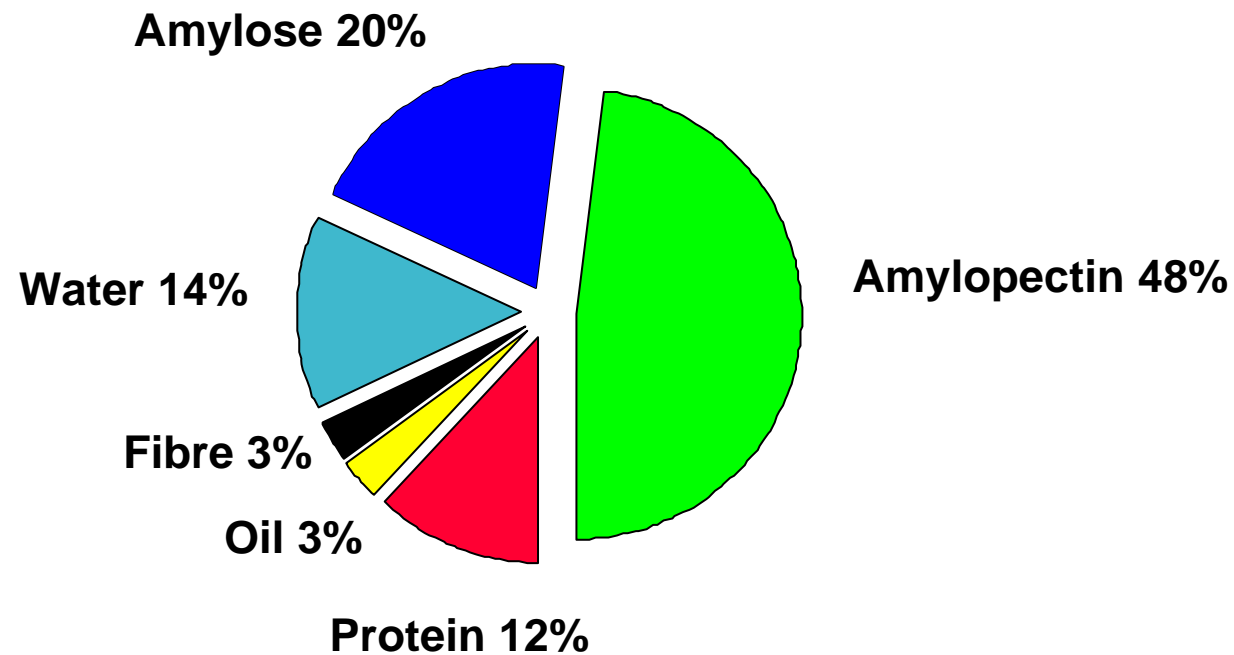
- Breeding for bread and biscuit making has been successful but future for bread in particular more difficult due to genetic and N/environmental limitations (**functionality at low N and PHS**)
- Distilling and bio-ethanol require minor adjustments
- Research objectives:
  - Further improvement in protein quality for bread, possibly accumulation of desirable minor genes for LMW glutenins and gliadins
  - Reliability
  - Feed and food nutritional value
  - Separation of proteins as more grain used for starch



Courtesy of Bingham and Summers



# Winter wheat composition



# Breeding Methodology



# Wheat Breeding: Challenges and Research Opportunities

- New marker systems
  - **SNP's**
  - Sequence chips
- Practical genomics (including forward and reverse genetics for gene function)
  - E.g. INRA Clermont Ferrand have carried out physical mapping of wheat chromosome 3B
    - 56952 fingerprinted BAC's
    - 1036 contigs
    - 811 MB coverage (82% of chromosome)
    - 1443 molecular markers anchored (SSR, ISBP, EST, Dart)
- Offers huge potential to accelerate breeding through marker development, MAS, association genetics, gene mining, mutation breeding, gene cloning, gene sequencing – all of which will require significant developments in bio-informatics
- Translational research effort, involving commercial breeders, **essential** to link genetic sequences to traits in varieties



# Priority Traits



# Wheat Breeding Priority Traits List

- Intransigent pests
  - Insect pests such as **wheat bulb fly** and **aphids**
    - Clear environmental as well as production benefits
    - Possible approaches include current varietal differences, attractants, physical barriers, toxic agents (as seen in OBM)
- Intransigent diseases
  - Fungal pathogens **Take all** and **ergot**
    - Take all: known alien leads (e.g. *Agropyron caninum*), Rye substitutions
    - Ergot: confirm varietal differences - if inadequate move to broader germplasm
    - Durable resistance to foliar pathogens
- Yield potential and associated agronomic traits
  - Includes resource utilisation efficiency!
  - Increase biomass and harvest index
    - Understand existing variation including recent advances with Robigus/Glasgow/...
    - Photosynthetic efficiency, C3, C3/4, C4
  - Genetics of plant and apical development (morphology and phenology)
    - Designer ideotypes e.g. slow apical development + overwinter biomass accumulation + daylength response + adequate straw
- Quality parameters and novel end use
  - Stability in pasta, bread and biscuit making properties
  - Feed conversion
  - Bio-ethanol production



Courtesy BWB

