Take-all Workshop
24th February 2006

Purpose & Objectives

Peter Jack, RAGT

Workshop Objectives

- Why are we here?
  - Much historical take-all research in UK - but this has diminished over the years – difficult to make progress!
  - But importance of take-all has not diminished!
  - BWB (and other breeders) have identified “Resistance to take-all” as one of their Priority areas
  - Questions:
    - Have new technologies made this a more realisable objective?
    - Are we better equipped to integrate and deploy new forms of resistance?

Workshop Objectives

- What do we need to do
  - Do not re-invent wheel
    - We need to be fully aware of all that was done historically to avoid negative approaches and pick up promising leads
  - This workshop will help in collating and disseminating such information
  - List options
  - Then focus on most promising lines of research

Workshop Objectives

- What are the next steps
  - Build on today – and not go back to day jobs and forget about it!
  - Breeders to keep profile high with BBSRC, DEFRA, WGIN, EU networks, global initiatives…..
  - Academics to think about project proposals (with close breeder linkage!!)

Take-all: new possibilities?

Neil Paveley

John Spink

ADAS

What has changed?

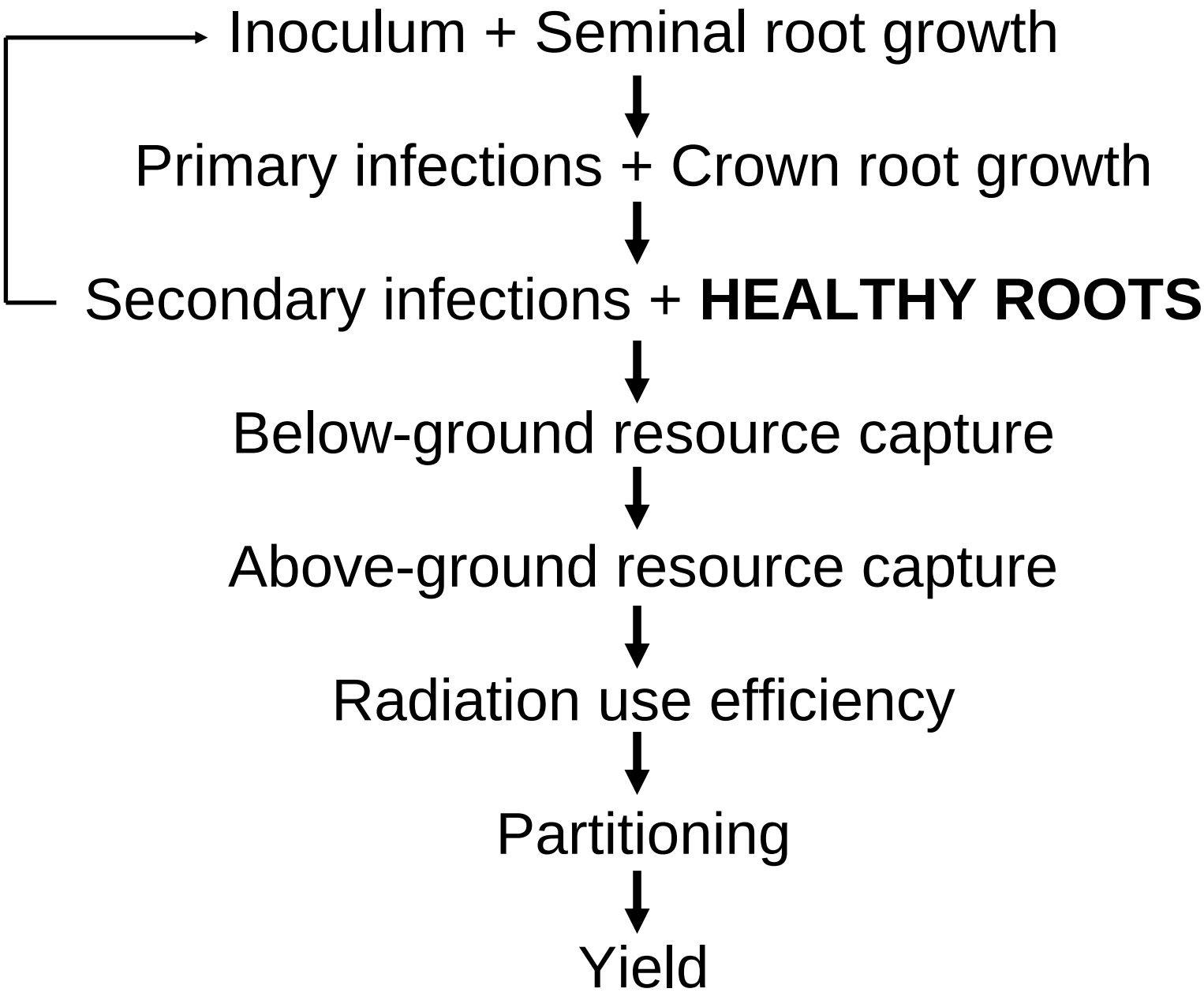
Economics and 'Politics'

- £60/tonne
- Agri-environment schemes
- Energy crops
- Sustainability aims

What has changed?

Knowledge

- Quantitative mechanistic research
  - epidemiology
  - resource capture
- Data sets in sensible units !


Inoculum + Seminal root growth
Primary infections + Crown root growth
Secondary infections + HEALTHY ROOTS
Below-ground resource capture
Above-ground resource capture
Radiation use efficiency
Partitioning
Yield

What has changed?

Tools

- Wide hybridisation/embryo rescue
- Cytogenetics
- Markers
- Diagnostics
- Sequencing
- Taxonomy

Epidemiology & Modelling of Take-all

Christopher Gilligan
Epidemiology & Modelling Group
Cambridge

Doug Bailey
Epidémiologie, Sol et Systèmes Group
BiO 3P - Agrocampus Rennes INRA

Where are we now?

Epidemiology

- Do we know enough?

Parameterisation

- Can we measure what we need to?

Screening control methods

- Can we use epidemiology to improve our predictions?

Epidemiology & Modelling of Take-all

Derivation of an epidemiological model for take-all

- **Simplifying epidemics**
- **Primary and secondary infection**
- **Dealing with consecutive crops**
- **The pathozone**
- **Scaling-up**
- **The way forward**
- **Questions**

Summary: Where are we now?

Epidemic models

- *Primary and secondary infection*
- *Stochasticity & spatial heterogeneity*
- *Dynamics over consecutive crops*
- *Criteria for invasion and persistence*

Parameterisation

- *Placement experiments*
- *Population experiments*
- *Micro-plot experiments*

Screening control methods

- *Chemical*
- *Biological*
- *Genetical & crop ideotype*

What are the big epidemiological questions?

Invasion

Why do some diseases take off and others do not?

Persistence

Why do some races and diseases die out, some co-exist and others

Variability

How can we translate variability into risk?

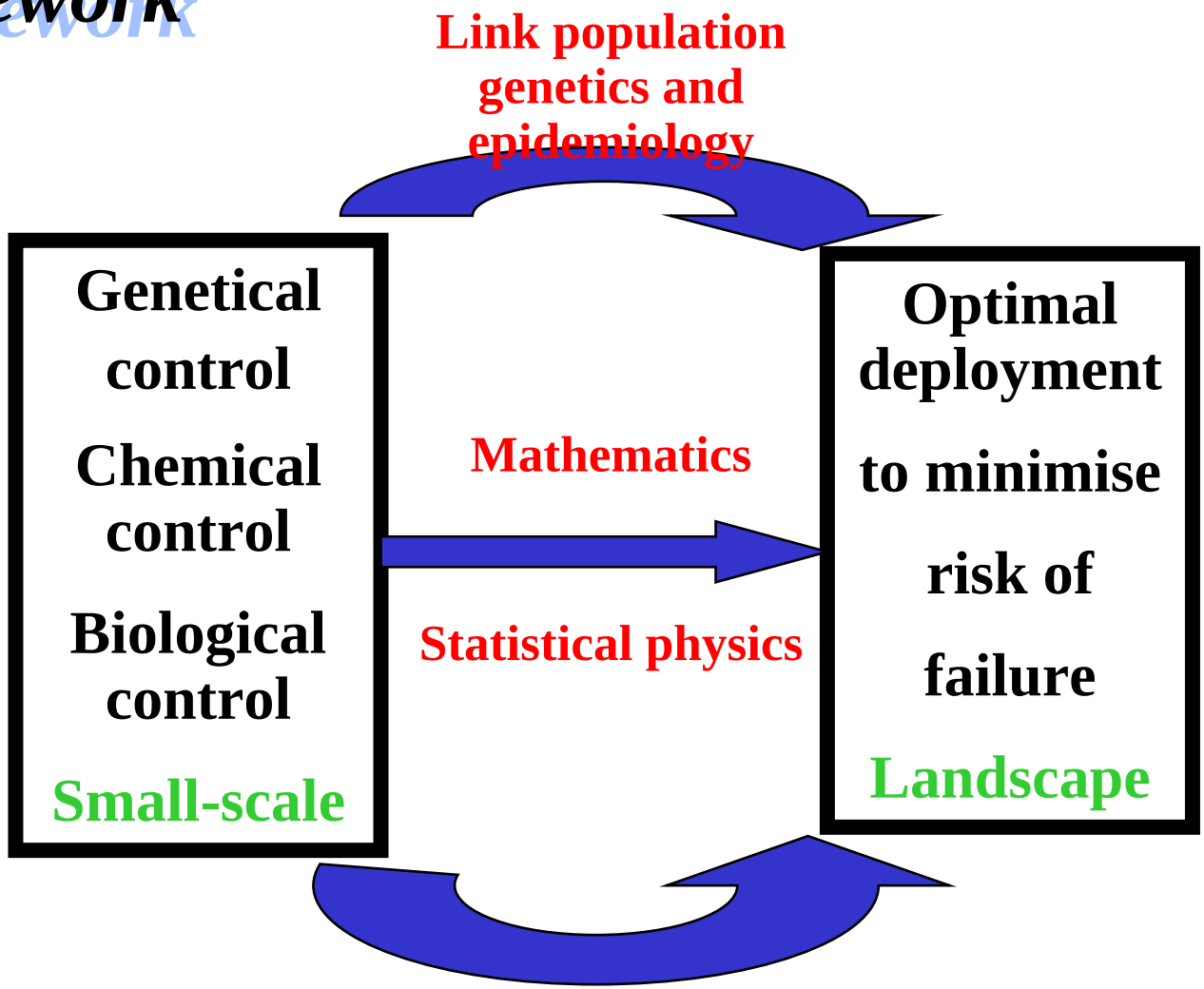
Scale

New infections occur at the small scale but problems happen at the large scale: how can we scale from the individual to the population?

Control

How can we use this information to optimise the deployment and durability of control methods?

Vision: Epidemiological-Genetic-Economic Framework



Summary so far …

Motivation

Matching spatial scales of epidemic and control strategies

Model structure

Control of primary infection can limit epidemics even when secondary infection occurs

Simple invasion criteria identify strategies for disease control

Biocontrol

Stochastic analysis allows prediction of risk of failure of control

The current state of knowledge on genotype variation in rooting and resource use efficiency, and interactions with take-all.

John Foulkes

Division of Agricultural and Environmental Sciences

The University of Nottingham

Conclusions

- Root length density at depth in wheat is insufficient for effective sub-soil water and N capture.
- Genetic ranges in RLD at depth sufficient to impact on water and nitrate capture.
- Take-all affects plant growth by reducing water and nitrate capture.
- Below-ground resource capture only affected when Healthy Root Length Density falls below a critical level, approximately 1 cm cm^{-3}.
- TAI not sufficient to explain impacts on crop growth. Root growth and water and N availability must also be taken into account.

Work funded

Changes in population structure of the soil-borne fungus *Gaeumannomyces graminis* var. *tritici (Ggt)* during continuous wheat cropping

L. Lebreton, P. Lucas & A. Sarniguet

UMR BiO3P, INRA / Agrocampus Rennes, 35653 Le Rheu, France

IV. Other studies that demonstrated *Ggt* populations were divided in two genotypes

1. At Rothamsted (UK)

- Bateman *et al*., 1997
  - ✓*Ggt* isolates from several sites (UK)
  - ✓Two RFLP types :
  - ✓One type more frequent from second wheat crops

- Freeman *et al*., 2005. *Plant Pathol.*
  - ✓Differential sensitivity between T_1 and T_2 to silthiofam

2. At the department of Land Systems and Landscape Ecology (Germany)

- (Augustin *et al*., 1999) . *J. Phytopathol*
  - ✓*Ggt isolates from several sites in Germany*
  - ✓*Two types*

- Augustin *et al*., 2004. *Soil Biol Biochem.*
  - ✓Two types with different pathozones

Take-all, Crop rotation, Intercrop ?

- Crop rotation is an efficient mean of control of take-all
  - and more broadly of most of soil-borne pathogens
  - but there is a low economic interest of some break crops
  - and a large predominance of wheat and barley in the market demand and thus in the cropping systems
- Could better management of the intercrop period be an opportunity ?
  - Maize/Winter wheat/Winter barley/ ...
  - or M/$I_{M\text{-}WW}$/WW/$I_{WW\text{-}B}$/WB/$I_{WB\text{-}M}$/...

Intercropping / summer fallow

- In France, between crops range from 1.5 to 9 months depending on the crop following WW
- Results from different management of the intercrop between two WW showed that
  - bare soil gives the lowest disease incidence and severity
  - leaving wheat volunteers gives the highest
  - mustard, oat and ray-grass give significant reduction
  - interaction with soil cultivation (burial of SF residus ?)
  - which is also important for inoculum dispersal and patchiness of the disease

Ennaïfar S, Lucas P, Meynard JM, Makowski D, 2005, EJPP, 112, 167-181

Gosme M, Willocquet L, Lucas P. Spatial pattern analysis of take-all disease of wheat, submitted.

Strategies for improving resistance to *Gaeumannomyces graminis in wheat*

Bill Hollins, RAGT

- **Search for variation in wheat**
- Actively breed/select
- Use other species:

  Oats

  rye

  Aegilops

  Agropyron

  Haynaldia

  Hordeum

Strategies for improving resistance to *Gaeumannomyces graminis in wheat*

- **Search for variation in wheat - waste of time**
- **Actively breed/select - speculative at best**
- **Use other species:**

Oats	**-danger of selecting for *var. avenae***
rye	**- good resistance; ?gene suppression**
Aegilops	**- probably small effects, ??stack genes**
Agropyron	**- good resistance, can we transfer**
Haynaldia	**- good resistance, can we transfer**
Hordeums	**- not promising**

don’t forget the hydroxamic acids

Introgression

- Bill Hollins: host resistance - including aliens
- Pat Heslop-Harrison: prospects for introgression
- Richard Gutteridge: testing methods
- PHH4@LE.AC.UK www.molcyt.com

Take-All and Alien Resistance
Why no success?

- There are no specific ‘resistance genes’:
  ‘diffuse genetic control’; ‘non-host resistance’
- Testing is inadequate
- Introgression possibilities have not all been explored
  - Key chromosomes missed
  - Key genotypes not tried
  - Key species not tested
- Resistance genes not expressed in wheat background

Molecular Cytogenetics Outcomes & Applications

- Measuring and classifying diversity
- Tracking and directing what happens in selection
- Crossing and recombining diversity
- Expressing diversity
- New crops
- New ploidies
- Alien chromosome introgressions
- Chromosome stability
- Recombination
- Impacting evolution:
  - Speciation, Crop domestication, Landrace selection, Plant breeding

Richard Gutteridge, Rothamsted

WINTER WHEAT VARIETIES AND TAKE-ALL

Bioassay of soils

- Soil core bioassay- Take-all infectivity of the soil.

- Bulk soil bioassay- maybe used in different ways:- a) Fungicide testing
  b) Soil suppression tests
  c) Susceptibility tests

Summary

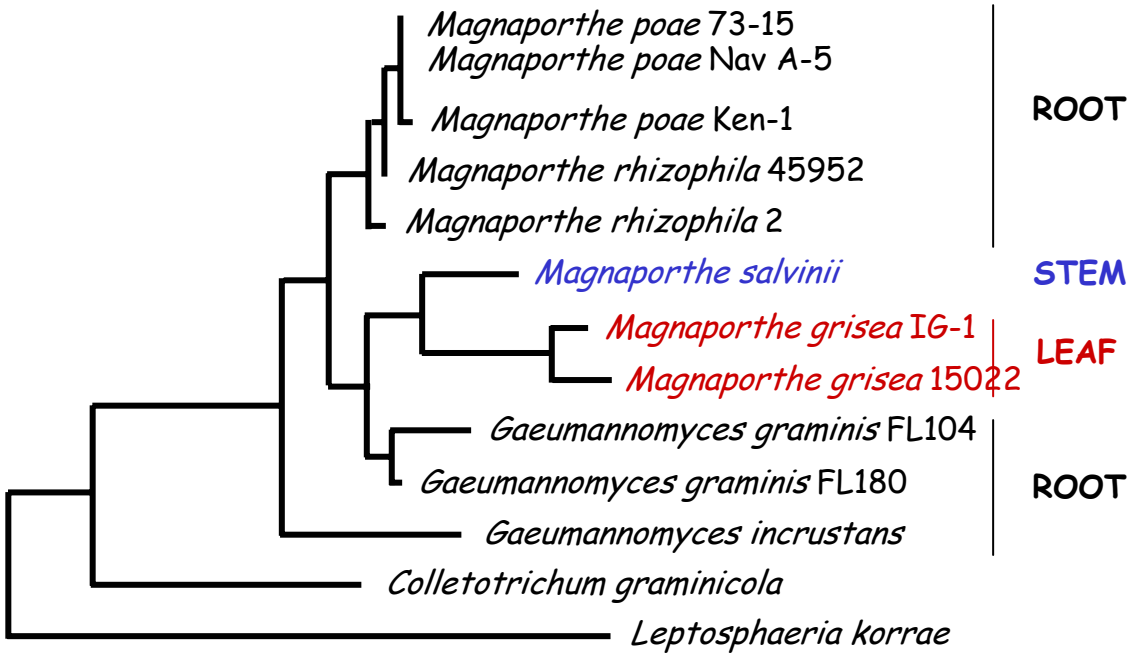
- The build-up of the take-all fungus under a first wheat crop may differ between wheat varieties as shown by the soil core bioassay.
- Soil bioassay maybe used to identify likely sources of resistance/tolerance to take-all but inoculum concentration critical i.e. below 50% root infection.

Rice blast and take-all
Anne Osbourne, JIC

Magnaporthe grisea

Gaeumannomyces graminis

The take-all fungus is a close relative of the rice blast pathogen *Magnaporthe grisea*



Comparative Genome Analysis of Foliar and Root Infecting Members of the Magnaporthacae

USDA/NSF Microbial Genome Program
March 2nd 2006
2 year project

The benefits

- Comparative analysis is expected to unveil features that determine the nature of the infection process:
  - Life cycles
  - The disease process
  - Tissue specificity, host range
- The order of evolutionary events
  - Did *M. grisea* evolve from a root-infecting ancestor?
- Why are *G. graminis* and other related root-infecting fungi difficult to transform?
- New strategies for disease control

Take-all: inoculum and populations

Geoff Bateman

ROTHAMSTED RESEARCH

Population structure in populations of *Gaeumannomyces graminis* var. *tritici*

- Possible implications for different sub-populations:

  Associated with host (Bateman *et al*., 1997)

  Associated with epidemic stage (Bateman *et al*., 1997?; Lebreton *et al*., 2001)

  Associated with sensitivity to silthiofam (Freeman *et al*., 2005)

  Associated with wheat host genotype?????

Take-all: effects of grass weeds and sown grass covers

Some grasses can adversely affect take-all in following wheat by:

- Transmission of inoculum
- Suppression of antagonistic microbiota

Ongoing research:

- Crop/grass sequence experiments
- Soil suppression testing
- Microbial community diagnostics
- Gene activity
- Chemical signals

Take all & Sustainability

Roger Sylvester-Bradley

ADAS Boxworth, Cambridge

Sustainability issues

- Energy ... productivity
  - rural viability … land use … biofuels … food & fuel security … exports
- Water
  - hydrological effects … pollutant concentrations
- Nitrogen
  - inefficient use … early & high requirements … high grain protein
- Other chemicals
  - input levels … efficiency ? … residues?

Summary - value of less take all

- Productivity costs
  - better energy conversion - yields
  - lower production costs
  - **flexible land use**
- Water
  - more needed per hectare
  - less needed per tonne
- Nitrogen
  - better late uptake
  - more fertiliser required / hectare
  - less fertiliser required / tonne
  - more difficult to achieve milling quality