New and Emerging Technologies for Crop Protection

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WRc
Swindon 9th November
A world without pesticides

• Dangerous leap into the unknown or long overdue change for the better
• A staged change rather than paradigm shift
• A multi-tiered strategic change
Crop Protection Futures for Arable

• Cost drivers and scale require large scale sustainable solutions
• Synthetic chemistry will continue to have a role for decades to come
• Crop protection will need to be smarter, more integrated and tailored to the problem
• Learning from other sectors
Challenges in the health sector

- Change in emphasis in health care from cure to prevention
- Dealing with illness linked to life style rather than infection
- Decline in new drug discovery
- The growth of drug/antibiotic resistance
- Challenging regulatory environment
- ALL VERY FAMILIAR !!
Responses to the challenges

- Move from cure to prevention
- Treating the patient rather than the disease - the growth of personalized medicine
- Move from conventional drugs to new therapeutics (immunotherapy)
- An awareness of our second genome ‘the microbiome’
- More effective links between clinicians/ patient needs and researchers - rapid deployment of new science
- Use of multi-tiered (eg: combination) treatment strategies
- An awareness that effective translation is dependent on firm foundational research

• Better Integration of existing (chemical) and developing (biotech, engineering) technologies
• Fast tracking translation of basic science to new approaches in pest/ weed control (eg: omics)
• National resistance monitoring and intervention
• Better use of data systems/ predictive modeling
• Knowledge transfer
• New skills development
• Proactive engagement with regulators
Delivering a new strategy

- Short term wins
- Better stewardship of remaining products
- More effective engagement with regulators
- Quarantine
- Precision application
- Longer term wins
- Innovation in new approaches & counteracting resistance
- Better use of social science and knowledge exchange to deliver outcomes
The importance of social science

Genetics
- Enabling technologies – new varieties

Non-genetic technologies
- precision ag, new crop protection technologies, improved engineering

Behaviours, sociotechnical, agribusiness

Biological constraints
- Variety
- Weeds
- Pests & diseases
- Soil
- Water

Socio-economic constraints
- Costs
- Credits
- Tradition & attitudes
- Knowledge
- Policies & regulations

APPLICATION OF ENABLING TECHNOLOGIES

ADOPION OF BEST PRACTICES

TRANSLATIONAL RESEARCH

Modified from: http://www.fao.org/docrep/x7164t/x7164t03.htm
Quarantine and Prevention

- Where applied at a national level has proven successful in exclusion of exotics
- More needs to be done at regional/farm level
Making better use of what remains: Precision application and delivery of crop protection

- Precision spray treatments delivered on tractors or even by drones
- Precision requires decision
- Need for better diagnostics to deliver optimal solutions
New Genetic Prevention Technologies

• New approaches for accelerated genetic improvement for disease and pest resistance
• Genome editing (loss of function)
• Gene targeting, pyramiding, synthetic biology approaches all possible for most arables.
• But acceptable?
• Most likely when outcomes arrived at by guiding conventional approaches
Manipulating plant associated microbes for disease and pest resistance, improved NUE and abiotic stress tolerance.
Protection through detection

• Greater deployment of molecular diagnostics for early detection and directed solutions
• Real time detection linked to control decision systems
• An approach under investigation in the CHAP lab to field units
Future field detection technologies

- Oxford Nanopore USB sequencing
- Extending types of biomarkers that can be identified beyond DNA/Antibodies
- Ligand arrays
- Surface ionization high resolution MS
New Curative solutions from existing technologies

• Active interventions will have to work more effectively with ‘latent’ improvements in resistance
• Similarly chemical control will be integrated with precision agriculture, robotic weeding
• Increasing use of herbicide mixtures
• Combination therapy
• Greater use of synergists/ safeners
• Exploration of technologies widely adopted in developing nations and the growth of Biologics
Natural therapy


Also with finger millet, *Eleusine coracana*: Midega et al. (2010), *Int. J. Pest Man.* 56: 145
Using synthetic biology to mass produce natural products for applications as agrochemicals

Feedstock → 4-coumaroyl-CoA ligase → pp-CoA thioesters → reductase → RDT → dihydrochalcones → chalcone synthase → C-glucosyltransferase → Product

Endogenous yeast reductase

pGAL1 → 4CL → 2A → CHS → 2A → UGT → CYC1 term → Product
New ways of conducting crop protection research

BGRI: Herbicide resistance in black-grass

A major (£3.5 million) interdisciplinary project that harnesses latest thinking in biochemistry, ecology, molecular evolution and weed science

Integrated with knowledge exchange with the farming and agronomy sectors

Basic science directly linked to user needs

Source: Defra
First two field seasons completed

- 71 farms, 138 fields surveyed & resurveyed
- 190 seed populations collected
- Field management data collated
Linking the farmers into the research programme
The Omics of Resistance

A search for functional biomarkers of NTSR
AmGSTF1 as a functional biomarker of NTSR

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<tr>
<th>Populations</th>
<th>Enhanced Metabolism</th>
<th>ACCase TSR</th>
<th>ALS TSR</th>
<th>AmGSTF1 antibody</th>
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MHR-linked *amgstf1* gene confers a resistance phenotype

**Physical phenotypes**

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<th>Soil</th>
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<tr>
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<tr>
<td>Chlorotoluron</td>
<td>![Plant images]</td>
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<tr>
<td>Alachlor</td>
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<tr>
<td>Atrazine</td>
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</table>

- Vector – negative control
- Line 8 – mid AmGSTF1-expressor
- Line 12 – high AmGSTF1-expressor

**Metabolite profiles**

**Transgenic Arabidopsis**

- Amount present (nmol per gram FW)
- Glutathione, Major anthocyanin, Major flavonoid

**Black-grass**

- Amount present (nmol per gram FW)
- Glutathione, Major anthocyanin, Major flavonoid

Cummins and Wortley et al. (2013), *PNAS*, 110, 5812
Identifying new routes to counteracting resistance
Real time diagnostics: Moving to prevention rather than cure

LAMP reaction

Clondiag
Some possible outcomes for the water industry

- Potential for greater uses of pesticide mixtures used to combat resistance
- New chemistries entering the environment as smart /functional formulations
- Microbial inoculants
- Natural products / biologics
- RNAi
New approaches needed for the registration of next generation pesticides

Sets out restrictions on selling, supplying or storing pesticides and precautions to protect the health of humans, the environment, and particularly water, when using pesticides

- 1986
  - The Control of Pesticides Regulations (SI 1986/1510)
- 1991
- 1997
  - Control of Pesticides (Amendment) Regulations (SI 1997/188)
- 2005
  - The 91/414 Directive is implemented in the UK by the Plant Protection Products Regulations (PPPR)
- 2011

Environment + Safety ~ Risk vs. Hazard (endocrine disruptors only) = Cost increase in registration
Acknowledgements

The University of York

Black-grass herbicide resistance initiative

Durham University

BBSRC
biosoence for the future

syngenta