Crop health: Better decision making

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Professor of Applied Plant Pathology

Leading the way in Agriculture and Rural Research, Education and Consulting
Crop doctoring

- Wider issues around managing crop health
- Contribution of applied science to better evidence & better decision making
- ‘No such career’ compared to doctors or vets
- Multiple hosts…many specialist disciplines
- Where does the generalist fit?
Careers for plant doctors

• Why is plant doctoring not seen as a career?
• Scientists rightly judged on the quality of their science through peer review of papers
• Applied / general journals score lower
• Research Excellence Framework now recognises impact
• Re-attach value to the generalist & to effective KE

Russian radios
Measures of productivity – ask and it will be given
Better links needed

Industry

Scientists

Teaching

science gives evidence base
Case study Ramularia – applied through to basic science

- Leaf spotting first picked up in monitoring and clinic samples
- Levy board funding identified initial control strategies
- Efficacy trials from companies
- Core research identified risk warning criteria
- Warnings now issues to growers at key growth stages
- Ramularia genome sequenced and submitted for publication
- Spin out projects with industry/PhDs
Making better crop protection decisions

- Decisions about actions to manage crop/plant health issues are made within a hierarchy of ‘off farm’ policy and regulatory issues and ‘on-farm’ information.

- Better decisions = more efficient and sustainable plant protection / crop production.
An accurate diagnosis is only the start...

- Deciding to treat
- Treatment options
- Client attitude to risk
- Managing crop health has economic, social and environmental costs
- Multiple decision makers / shared decision making

Better decisions…
Crop clinic – GP and A&E in one

- Seasonal experience in common and unusual problems
- Early warning of new problems
- Evidence gathering
- Assessing risk
- Decision making
- KE and engagement with stakeholders
Combinable crops

Straight forward diagnoses are only a small part of the job
Cash crops – high stakes
Oops ...... operator error
The sublime to the serious....
The ones that scare you…

- wart disease
- fireblight
and the ones that make your week...

Omphalina in cereals

(picture courtesy TEAGASG)

Halo spot in barley
Even the definition of diagnosis is blurred...

- Working / operational description of a diagnosis presented to differing groups of practitioners or students
Group 1 – BASIS trainees
Group 2 – 2 year students
Group 3 - Consultants
Group 4 – UKPD diagnosticians
Managing plant health

Prevent ingress of new problems

Manage established disease burden
Defining plant health priorities – policy context

: a classic example of a multilevel (hierarchical) decision problem

“A key characteristic of agricultural (or economic) policy problems is that the government, or other policy makers, have only a limited range of variables under their direct control.”

Candler et al. 1981

Lower down the hierarchy, a myriad of decentralized decision makers – including farmers, forestry and woodland managers, smallholders, commercial nurseries and garden centres and the gardeners who use them – all make decisions that may impact plant health, following a variety of behavioural rules.
Good decision making underpins good farming

But .. constraints on decision making

- Regulatory withdrawal of pesticides / resistance development
- Market barriers to uptake of some possible options such as new varieties.
Current EU framework aims to protect European agriculture and forestry by preventing the entry and spread of non-native harmful organisms of plants.

- Increased risks arising from globalisation
- Insufficient focus on prevention in relation to increased imports of high risk commodities
- A need to prioritise harmful organisms at EU level across all Member States
- A need for better measures for controlling the presence and natural spread of harmful organisms which manage to enter the Union territory
- A need for modernising and upgrading the measures concerning the phytosanitary control of intra-EU movements (plant passports and protected zones).
“The Plant Health Risk Register represents a major step in implementing the recommendations of the independent Task Force on Tree Health and Plant Biosecurity. It is a tool for government, industry and stakeholders to prioritise action against pests and diseases which threaten our crops, trees, gardens and countryside.”

The Food & Environment Research Agency
Good decision making

- Helping growers to judge risk and make better decisions

- Fungicide resistance as an example of judging risk in a more complex environment
Issues particular to UK

- Relatively high disease burden
- Intensive crop production
- High yields
- Conducive weather
- High level of inputs
Judging risk in a crop context

http://www.gov.scot/Publications/2014/12/2462/5#c4
Mean temperatures spring 2012-2015 compared to long term average
Underlying trends / seasonal variation

- Fewer hard winters
- Limited rotations
- Susceptible but marketable varieties
2011/2012 crop season

- Wet autumn
- Poor overwintering in wet soils
- Spring drought in South (not in north!) wet all summer
- Difficulties in timing sprays
- Lack of sunshine
- Low responses to fungicides
- Delayed 2012 harvest
2012 /2013 crop season

• Delayed 2012 harvest led to late drilling
• Record levels of spring crops
• Cold spring/slow growth
• Low disease levels
• Hot July lead to early ripening of some crops
• Low responses to fungicides
2013/2014 season

- Early drilling
- Warm autumn with disease present early
- Very few winter frosts
- Early growth of crops and diseases in spring
- Warm / wet conditions over critical timings
- Exceptionally high disease levels
- Good potential in crops
- Huge responses to fungicides
2015….started same way so disease burden high …cold spring reversed
Variable responses in trial data
Variable responses in trial data

Yield by year (All regions)
Sustainable crop protection issues

• Very different yield potential in crops between seasons
• Very different disease pressure between seasons
• Different growth patterns each year
• Effective control interventions vary over time
• Economic, environmental and social costs to treatment
• Need for more integrated practices
• What does IPM mean to stakeholders
Group 2 – industry workshop

Crop rotations
Crop protection
Insecticide
Cultivation
Minimise negative impacts
Awareness of alternatives
Soil management
Physical control biosecurity
Thresholds holistic view
New approaches
Fungicide human health
Use of pesticides tillage
Sustainability
Reduce fertilizer
Pest thresholds
Pest avoidance
Open mind
Environmental health
Timing
Appropriate chemical control
Pest management biological control
Cover crops
Modern chemistry mechanical control
Fertilizer application
Disease avoidance
Improve yield environmental tools
Cultural control
Natural control
Chemical control
Good decision making in the field

- Starts with accurate diagnosis
- Gathering of evidence
- Quantification of risk of economic damage
- Appraisal of options
- Attitudes to risk vary

Ear blight in barley
Judging risk

What information is available to decision makers?

- Generic risk / own experience
- Evidence from in-season monitoring / warnings
- Specific site / crop information / diagnosis
Disease pressure varies each season – monitoring and surveillance are important tools.
What information is available:

Disease pressure varies with season

Source AAC data
Poor control sometimes explained by difficulties with timing spray applications.

- **T0 spray**: Advanced seedlings
- **T1 spray early**: Often close to flag spray
- **T2 spray gap long**: T4 spray?
Trial data

- How different could it get from 2013
- Changes to Fungicides
- WOSR – What to Spray and When
- Seed Treatments - What to test different seed for
Using the most effective options
Septoria
Sources of evidence - Detailed met station data (and spore trap data)

- Spore trap data can be used to track emergence of established, emerging or as yet unknown alien pathogens
- Paired weather and site data can be used to investigate epidemiology and key drivers
Predicting disease risk…..

- Simple thresholds
- Accumulating risk along a time line
- Available evidence / data
- Effectiveness of interventions
- Weighting of factors
- Risk algorithms
Developing risk methodology


Ramularia leaf spot of barley. Logistic regression of crop status (need for treatment, binary variable 1/0) on the single explanatory variable ‘AUDPC’. Data points are indicated ×; the point ■ indicates the economic threshold value for malting-quality barley crops based on 2010 prices.
Developing risk methodology

Hughes, G & Burnett, F. J. Information graphs for binary predictors. Phytopathology January 2015, Volume 105, Number 1: 9-17 (example below based on FHB risk prediction)
Eyespot – Calculation of risk on a timeline

Step 1. Pre-sowing risk score

<table>
<thead>
<tr>
<th>Factor</th>
<th>Level</th>
<th>Risk points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>East</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>West</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Soil type</td>
<td>Light</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Previous crop</td>
<td>Non-host</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other cereal</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tillage</td>
<td>Minimum till</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plough</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Sowing date</td>
<td>Late</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(before or after 6 October)</td>
<td>Early</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Pre-sowing risk score
## Step 2. Spring assessment to determine final eyespot risk

### Eyespot disease incidence at GS31-32

<table>
<thead>
<tr>
<th>Pre-sowing risk score</th>
<th>1%-4%</th>
<th>5%-9%</th>
<th>10%-14%</th>
<th>15%-19%</th>
<th>≥20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>L</td>
<td>LM</td>
<td>M</td>
<td>MH</td>
<td>H</td>
</tr>
<tr>
<td>5-9</td>
<td>LM</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>H</td>
</tr>
<tr>
<td>10-14</td>
<td>M</td>
<td>M</td>
<td>MH</td>
<td>MH</td>
<td>H</td>
</tr>
<tr>
<td>15-19</td>
<td>MH</td>
<td>MH</td>
<td>MH</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>20-25</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

### Final eyespot disease risk

<table>
<thead>
<tr>
<th>Final eyespot disease risk</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low risk (L)</td>
<td>None required</td>
</tr>
<tr>
<td>Low-medium risk (LM)</td>
<td></td>
</tr>
<tr>
<td>Medium risk (M)</td>
<td>Treatment may be justified where eyespot has been a recurring problem, leading to consistent yield reduction</td>
</tr>
<tr>
<td>Medium-high risk (MH)</td>
<td></td>
</tr>
<tr>
<td>High risk (H)</td>
<td>Treatment may be justified even in fields where eyespot has been known to rarely cause yield damage</td>
</tr>
</tbody>
</table>
# ‘Mycotoxin’ risk score

<table>
<thead>
<tr>
<th>Factor</th>
<th>Details</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region (see map)</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>Very low</td>
<td>-4</td>
</tr>
<tr>
<td>Previous Crop</td>
<td>Maize</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0</td>
</tr>
<tr>
<td>Cultivation</td>
<td>Direct drilled</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Standard non-inversion tillage</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Intensive non-inversion tillage</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Plough (soil inversion)</td>
<td>0</td>
</tr>
<tr>
<td>Wheat variety</td>
<td>RL Resistance rating 1-5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>RL Resistance rating 6-9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>RL Resistance rating unknown</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Your pre-flowering score</td>
<td></td>
</tr>
<tr>
<td>T3 fungicide</td>
<td>Under 50% dose rate of approved fungicide</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>50-74% dose rate of approved fungicide</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>75% or above dose rate of approved fungicide</td>
<td>-3</td>
</tr>
<tr>
<td>Rainfall at flowering (GS59-69)</td>
<td>More than 80 mm</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>40-80 mm</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>10-40 mm</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Less than 10 mm</td>
<td>0</td>
</tr>
<tr>
<td>Rainfall pre-harvest (GS87 to harvest)</td>
<td>More than 120 mm</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>80-120 mm</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>40-80 mm</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>20-40 mm</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Less than 20 mm</td>
<td>0</td>
</tr>
<tr>
<td>Your final score</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fungicide resistance – the current issues

- Fungicide resistance is eroding established actives and threatening newer ones
- Legislation brings additional threat of losses

So

- How do we use and steward all products to manage these issues?

Loss of field efficacy with QoI fungicides
Resistance management issues

- Loss of compounds with high activity and improved environmental profile.
- Reduced crop yield and quality
- Fewer options for effective disease control and resistance management
- Complex science, confused messages
- Difficulties in motivating industry to be collectively responsible
Introduction to the Fungicide Resistance Action Group -UK

- 20 members + 4 specialist members
- Key independent researchers
- Agrochemical representatives
- Independent agronomist
- Chemicals Regulation Directorate
Aims of FRAG- UK

- To gather and interpret reports of fungicide resistance issues
- Arrive at UK consensus view
- To promote practical guidelines on status and management of fungicide resistance in UK
- To give evidence base for regulatory decisions
- To indicate areas where R and D is required
- To publicise the above and reduce incidences of resistance
Sifting evidence – declines in efficacy over time

Half label rate

% control Septoria tritici

Proline
Opus / Ignite

Full label rate

% control Septoria tritici

Proline
Opus / Ignite

R^2 = 0.6289
R^2 = 0.596

R^2 = 0.6545
R^2 = 0.7434

R^2 = 0.7434
R^2 = 0.6545
Molecular characterisation of mutants

- **Mut 1 - SdhB**

  AA change: B- S 217 L
  
  *M. graminicola*: B- S 218 F (lab mutant)

- **Mut 11 - SdhB**

  AA change: B- N 224 I

- **Mut 111 - SdhB**

  AA change: B- N 225 I (lab mutant)
  
  *M. graminicola*: B- N 225 I (lab mutant)
  
  *B. cinerea*: B- N 230 I (field isolate)
Base line and UV laboratory mutants resistant to SDHIs

EC50 values of Rcc SDHI mutants and Scottish field population

EC50 values of Rcc SDHI mutants and Scottish field population.
Population genetic studies

Genetic structure of Scottish and Czech populations of *Rcc*

- Only one clonal pair in each population
- Populations undergo substantial sexual reproduction, with some asexual reproduction occurring during the season
- Possibly relatively quick adaptation to environmental changes (i.e. fungicide applications, new cultivars)
What can we do to manage resistance?

- Is dose rate important?
- Is application number important?
- How effective are mixtures?
- Would alternations be better?

Mix of regulation and stewardship
Key FRAG-UK outputs

- Website
- Guidelines
- Publicity (i.e. posters at HGCA / farmer or research events)
- Statements on topical issues (i.e. azole mixtures, SDHI usage)
- Talks at grower / industry meetings
- Papers / conferences
- UK regulatory authority contact – recommendations for label restrictions / changes

Knowledge exchange: Taking science to the field

Better evidence / better decision making

- Generalist overview / context / sense checking
- Field evidence on effective interventions
- Advancement in capability, ‘omics’, sensors
Thanks