Integrated Pest Management strategies for a changing climate – building-in resilience

Adrian C Newton
Food System Impacts of Pests & Pathogens in a Changing Climate. 19th – 23rd August 2019, Aspen, Colorado
Overview

1. Can we predict pathogen changes well enough for targeted IPM?
2. Complexity, connectivity, heterogeneity and diversity: the parameters of resilience?
3. Can complexity, connectivity, heterogeneity and diversity be managed PRACTICALLY?
4. SYSTEMS that exploit such resilience...
5. [APPROACHES to resistance breeding and management...]
Representative current and emerging pest and disease problems that could threaten barley food security.

- a) cereal cyst nematode
- b) Barley Yellow Dwarf Virus
- c) orange blossom midge
- d) Fusarium head blight
- e) cereal bacterial leaf streak
- f) rice blast (on barley)
- g) Ramularia Leaf Spot
- h) rhynchosporium or scald
- i) stem rust (on barley)

Barley: a resilient crop. Strengths and weaknesses in the context of food security.

Future environmental and geographic risks of *Fusarium* head blight of wheat in Scotland

Peter Skelsey • Adrian C. Newton

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Abstract Methods used to assess climate change risk for crop diseases often assume that both host and pathogen are present. Consequently, model output may misrepresent future growing seasons, due to a failure to reflect likely change at the landscape- and farm-scale and its impact on disease risk. In this study, data defining the spatial coverage of crops in Scotland were combined with spatially coherent, probabilistic climate change data to project the future risk of *Fusarium* head blight (FHB) in wheat. Primary inoculum was initially treated vulnerable to sea-level rise, with little additional risk of FHB. These projections, made by considering the temporal and spatial coincidence of host and pathogen species under various climate change scenarios, suggest that improved control of FHB might not be a high priority for future food security in Scotland.

Keywords *Fusarium* head blight (Gibberella zeae/Fusarium culmorum) • Mycotoxins • Climate change • Risk assessment • Inoculum dispersal
Prediction of pathogen change – possible?

Spot blotch infection. Percentage leaf area covered with symptoms and amount DNA/ng barley DNA

Powdery mildew infection. Successful fungal penetration

Complex interplay of future climate levels of CO2, ozone and temperature on susceptibility to fungal diseases in barley

B. L. Mikkelsen, R. B. Jørgensen, M. F. Lyngkjær
Plant Pathology, Volume: 64, Issue: 2, Pages: 319-327, First published: 08 July 2014, DOI: (10.1111/ppa.12272)
Influences on pest and pathogen threat to food security

Where does “diversity” (complexity, connectivity, heterogeneity and diversity) fit in?

- Extension service (e.g. USDA, ADAS, SRUC)
- International authority (e.g. FAO, CABI, UNESCO)
- Farmer / grower
- Administrative authority (e.g. country or political region)

- Plant
- Field
- Landscape
- Global land

- Crop stand
- Farm
- Continent

- Pesticides
- Phytosanitation

- Durable resistance
- Climate change adaptation effects

Red box: Measures are particularly relevant to climate change effects
Blue box: Scale and relevant type of knowledge exchange bodies

Newton, Johnson & Gregory, 2011. Euphytica 179, 3-18
Resilience index?

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Heterogeneity</th>
<th>Connectivity</th>
<th>Diversity high (8)</th>
<th>Diversity low (2)</th>
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<tbody>
<tr>
<td>Total number</td>
<td>[uniform / patchy distribution]</td>
<td>Complexity/heterogeneity</td>
<td>How different</td>
<td>How different</td>
</tr>
<tr>
<td>8 high</td>
<td>2 low</td>
<td>4 high</td>
<td>512</td>
<td>128</td>
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<tr>
<td>8 high</td>
<td>8 high</td>
<td>1 medium</td>
<td>512</td>
<td>128</td>
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<tr>
<td>2 low</td>
<td>2 high</td>
<td>1 medium</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>2 low</td>
<td>8 low</td>
<td>0.25 low</td>
<td>8</td>
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- Crop genotypes / traits
- Agronomy
- Spatial deployment
- Temporal deployment
- Policy drivers
- Supply chain implications
# Structured resistance gene deployment

<table>
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**a) Monoculture**

**b) Homogeneous**

**c) Structured**

Selection for:  

**a) Simple**

**b) Complex**

**c) Simple and Complex and Groups**

<table>
<thead>
<tr>
<th>Mildew</th>
<th>4.09&lt;sup&gt;a&lt;/sup&gt;</th>
<th>4.69&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2.61&lt;sup&gt;b&lt;/sup&gt;</th>
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<tr>
<td></td>
<td>LSD 1.06</td>
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<sup>1</sup> Percentage whole plant infection.
But on a REAL farm...

3 different varieties

Drill hopper

Pre-mixed

Sequential

In situ

Simultaneous
Patchy arrangements in the field

Yield
Mixtures cf. mono mean: 2005 +13%*** 2006 +17%***
Mixtures cf. mono mean: 2005 -34%*** 2007 -58%***

Rhynchosporium
Mixtures cf. mono mean: 2005 -34%*** 2007 -58%***

In situ
Pre-mix
-4%
+10%

Intercrops = bigger trait interaction potential = bigger responses
Mature direct drilled wheat compared with inversion tillage (plough & harrow) showing effect of disrupting soil microbe – crop on disease resistance expression in the field (UK, 2018)
Crop yields: first rotation 2011-2016: orange = integrated, yellow = standard
Thanks to:

Scottish Government (RESAS)
EU & other funders
Doug Christie (Durie)
Hutton Farm staff and Dave Guy

Thank you!
Examples of trophic interactions:

1. Rhynchosporium secalis on Hordeum vulgare
2a. Ramularia collo-cygni on Hordeum vulgare
2b. Pectobacterium atrosepticum on Brassicaceae and Solanum tuberosum
2c. Leptosphaeria maculans on Brassica napus
3. Arbuscular mycorrhizal symbioses
4. Ceratobasidium cornigerum on Goodyera repens

Trophic space change triggers

- Microbe range
- Microbe propagule
- Benefit
- Cost
- Invasion/Colonisation
- Pathogenicity
- Mutualist/parasite
- Sporulation/dissemination

Example trophic phase change triggers:
- All these are affected by climate change

Plant life cycle:
- Environmental
- Temporal
- Developmental

Seed | Dispersal | Establishment | Niche exploitation | Seed prod'n

Climate change affects:
- Seed prod'n
- Niche exploitation
- Establishment
- Dispersal
- Seed
Soil: biology and physics

Enhanced variation / virulence / new pathogens

Pest and pathogen populations

Crop yield and quality

Toxin production

Reduced pathogenicity

Improved crop substrate

Infection conditions reduced

Symptom expression triggered

Enhanced tolerance through mycorrhizae

R gene ON

Endophyte benefits

R gene OFF

Infection conditions enhanced

Poorer crop substrate

Enhanced inoculum

Reduced inoculum

Pathogen competition

Pathogen synergy

Enhanced pathogenicity

Climate Change

Likelihood probability

Manipulation feasibility

Heterogeneity

Mono-culture

Manipulation feasibility

Risk enhancement

Resistance elicitor; biostimulants

Conventional pesticide

Chakraborty & Newton, 2011. Plant Pathology 60, 2-14 (special issue on climate change)

**Figure 2** Influence of climate change on rate-determining processes that are the result of the complex interaction between the ‘enhancing’ (right) and ‘mitigating’ (left) influences on plant and pest/pathogen interactions. Rankings for likelihood probabilities and manipulation feasibility are initial approximations requiring critical review.
Crop system diversity signalling influences.