Potential for alternative products to control disease in agriculture

Neil Havis
A role in integrated control
Optimisation of Induced Resistance for crop protection

Elicitors in agriculture

Beneficial microbes shown to trigger induced systemic resistance (ISR)

1933
Chester reviews ‘acquired physiological immunity in plants’

1960–70
Kuc et al. – extensive studies on induced resistance

1961
Ross – empirical evidence of systemic acquired resistance (SAR)

1979
White – SA shown to induce PR proteins and SAR in tobacco

Mid-1970s
Probenazole launched in Japan

Early 1990s
SA found to be essential for SAR activation

1980–1990
Ciba begin screening for inducers

1990–95
Beneficial microbes shown to trigger ISR

1996
Acibenzolar-S-methyl (Blon) commercialised

1999–2010
IR products
- Harpin protein (e.g. Messenger)
- Chitosan (e.g. Eleaxa)
- Laminarin (e.g. Vacciplant)
- Reynoutria extract (e.g. Milsana)
- Benzothiadiazole derivatives (e.g. Tiamin, Isobanil)

2000
Inducers are commercialised (replace IR products)

Reglinski et al, 2023
Elicitors can be used to induce resistance.

There are various types of induced resistance. The main types are:

- Systemic acquired resistance (SAR)
- Induced systemic resistance (ISR)
Systemic Acquired Resistance (SAR)

- **Application of elicitor**
- **Systemic movement of signal**
- **Triggering of defences**
- **Enhanced resistance to further infection [broad spectrum]**

Salicylic acid is involved in the mechanism of SAR expression. SA triggers accumulation of PR proteins. However, SA is not the transported signal. Usually associated with resistance to biotrophs.
Induced Systemic Resistance (ISR)

1. Colonisation of roots by PGPR
2. Movement of systemic signal
3. Enhanced resistance to pathogen infection

Jasmonic acid is involved in induced resistance to insects and in ISR to PGPR. Exogenous JA can induce resistance. Disruption of endogenous JA accumulation prevents development of induced resistance. Usually associated with resistance to necrotrophs.
Range of ‘elicitors’ capable of inducing resistance

Agents or compounds that

- mimic action of natural elicitors e.g. Chitosan
- generate natural elicitors e.g. phosphate, phosphites
- mimic action of signals e.g. acibenzolar-s-methyl (BION/Innimisso)
- pathogens - prior infection (role for biologicals)
- mycorrhizal infection
Renewed interest - Elicitor (Bion) effect on clubroot galling
Using elicitor combinations

Elicitors applied in autumn and early spring

Elicitor combination controls light leaf spot on winter oilseed rape
### Year one field trials (3 varieties x 18 treats)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>T0 (GS 24)</th>
<th>T1 (GS 31)</th>
<th>T2 (GS45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Untreated</td>
<td>Untreated</td>
<td>Untreated</td>
</tr>
<tr>
<td>2</td>
<td>Laminarin</td>
<td>Laminarin</td>
<td>Untreated</td>
</tr>
<tr>
<td>3</td>
<td>Amino Flo 2.5 l/ha</td>
<td>Amino Flo 2.5 l/ha</td>
<td>Untreated</td>
</tr>
<tr>
<td>4</td>
<td>Bion</td>
<td>Bion</td>
<td>Untreated</td>
</tr>
<tr>
<td>5</td>
<td>AQ10</td>
<td>AQ10</td>
<td>Untreated</td>
</tr>
<tr>
<td>6</td>
<td>B subtilis</td>
<td>B subtilis</td>
<td>Untreated</td>
</tr>
<tr>
<td>7</td>
<td>Microthiol</td>
<td>Microthiol</td>
<td>Untreated</td>
</tr>
<tr>
<td>8</td>
<td>Phosphite</td>
<td>Phosphite</td>
<td>Untreated</td>
</tr>
<tr>
<td>9</td>
<td>Chitosan</td>
<td>Chitosan</td>
<td>Untreated</td>
</tr>
<tr>
<td>10</td>
<td>Laminarin</td>
<td>Laminarin + Amistar (0.25)</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>11</td>
<td>Amino Flo 2.5 l/ha</td>
<td>Amino Flo 2.5 l/ha + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>12</td>
<td>Bion</td>
<td>Bion + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>13</td>
<td>AQ10</td>
<td>AQ10 + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>14</td>
<td>Serenade</td>
<td>Serenade + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>15</td>
<td>Microthiol</td>
<td>Microthiol + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>16</td>
<td>Phosphite</td>
<td>Phosphite + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>17</td>
<td>Chitosan</td>
<td>Chitosan + Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
<tr>
<td>18</td>
<td>Untreated</td>
<td>Amistar 0.25</td>
<td>Revystar 0.4 + Folpet 0.5</td>
</tr>
</tbody>
</table>
Spring barley biologicals IPM trial

Late season Rhynchosporium, Edinburgh 2022

7= Microthiol
10= Laminarin
11= Amino flo
16= Phosphite

Untrt
No syn fungicide
+ Amistar @T1 and Revystar+Folpet @T2
No bio
Laminarin

- Approved in wheat.
- Application for use in barley and other cereals – late 2024
- Application for fruit, soft fruit and field vegetable crops – 2023
- Activity against *Zymoseptoria tritici*, *Blumeria graminis*, *Bipolaris sorokinia*, *Puccinia tritici*, *Drechshlera tritici-repentis*
Spring barley IPM trial cv Laureate

Yield benefit full programme = 0.9 t/ha
= £153 feed or £181 malt
(AHDB SACC Harvest 2018 – ex farm)

£51
Full

£39
Lam + Red rate

Yield t/ha
Barriers to elicitor uptake

Fig. 2. Factors affecting the expression of induced resistance in practice. IR, induced resistance. Adapted from Reglinski et al. Integration of induced resistance in crop production. In D Walters, A Newton, G Lyon, eds, Induced resistance for plant disease control: a sustainable approach to crop protection. Copyright (2007), with permission from Wiley-Blackwell, Oxford, pp. 201–228.
What is biocontrol?

*The reduction in the amount of inoculum or disease-producing activity of a pathogen accomplished by or through one or two more organisms other than man*

- Involves the exploitation of microorganisms ANTAGONISTS or BIOCONTROL AGENTS
- Naturally occurring in the soil & on plant surfaces FUNGI (e.g. *Coniothyrium mimitans*)
  BACTERIA (e.g. *Bacillus subtilis*)
  ACTINOMYCETES (e.g. *Streptomyces griseoviridis*)
How do biocontrol agents work

1. Parasitism or predation of one organism by another
   e.g. *Trichoderma* spp coil round hyphae of target fungi & produce enzymes to penetrate

2. Antibiotics – secretion of molecules harmful to target pathogens

   Photograph courtesy of Jim Deacon

   Antibiotics produced by *Trichoderma* spp
How do biocontrol agents work

- Competition – for space, nutrients, substrates etc

- Non pathogenic and pathogenic strains of *Fusarium oxysporum* compete for Carbon in soils
How do biocontrol agents work

• Cross protection
  • Treat plant with non-pathogenic or avirulent strain
  • Mild strains of *citrus tristeza virus* used to protect citrus from virulent strains in Brazil

• Growth stimulation
  • Many growth promoting substances have now come to market with claims of enhanced disease control
Developing a new biocontrol agent (1)

1. Harvest of source material from an appropriate environment

2. Isolation, cultivation and (ideally) identification of microbes

3a. Medium-high throughput disease assay

3b. High-throughput confrontation assay using strains from, e.g., microbe libraries

4. Plant assays in controlled environments
   a. diseased
   b. disease controlled by a BCA

5. Risk assessment and mode of action studies

7. Development, registration, licensing and marketing
Developing a new biocontrol agent (2)

High-throughput assay for Fusarium head blight using detached spikelets (Rojas et al., 2020a).
(a) Water control,
(b) *Fusarium graminearum* (Fg) control,
(c) Fg + *Pseudozyma floculosa*,
(d) Fg + *Penicillium olsonii*,
(e) set-up using large-well plates
Biopesticides in agriculture

- Dossier still required although 2013 scheme from CRD was designed to encourage new applications for approval.
- Reduced meeting fees if application goes ahead
- Products coming to market for fruit and vegetables e.g. D747 (Bacillus amyloliquefaciens subsp. plantarum strain)

<table>
<thead>
<tr>
<th>Product</th>
<th>Group</th>
<th>Crop</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerall</td>
<td>Biological</td>
<td>Rye, triticale, wheat</td>
<td>Pseudomonas chlororaphis MA 342</td>
</tr>
<tr>
<td>Iodus</td>
<td>Elicitor</td>
<td>Winter wheat</td>
<td>Laminarin</td>
</tr>
<tr>
<td>Serande ASO</td>
<td>Biological</td>
<td>Protected fruit and vegetable crops</td>
<td>Bacillus subtilis (strain QST 713)</td>
</tr>
<tr>
<td>Stage</td>
<td>Challenges</td>
<td>Choices</td>
<td>Risk</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Isolate selection</td>
<td>Access &amp; benefit sharing</td>
<td>Choose best or search for better</td>
<td>Nagoya protocol on access &amp; benefit sharing</td>
</tr>
<tr>
<td>Development</td>
<td>Production</td>
<td>Wet or dry formulation</td>
<td>Cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>Formulation</td>
<td>Powder or liquid</td>
<td>Too stringent? e.g. -20 deg C No suitable mixes</td>
</tr>
<tr>
<td></td>
<td>Shelf life</td>
<td>Temp &amp; humidity during storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compatibility with existing control</td>
<td>Mix with other products</td>
<td></td>
</tr>
<tr>
<td>Delivery systems</td>
<td>Seed treatments (coating –bio-primers)</td>
<td>Use existing equipment</td>
<td>Specialist equipment needed</td>
</tr>
<tr>
<td></td>
<td>Incorporation in growth medium, application to upper plant parts</td>
<td>Growth substrate, incorporation method</td>
<td>Incompatible with biome in the medium</td>
</tr>
<tr>
<td></td>
<td>Drench, broadcast, in furrow</td>
<td>Use existing method or specialist equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dusting, spraying vector dispersal</td>
<td>As above</td>
<td></td>
</tr>
<tr>
<td>Regulatory and industrial approval</td>
<td>Risk assessment (EU or EPA)</td>
<td>Scenarios</td>
<td>Refusal and onerous conditions</td>
</tr>
<tr>
<td></td>
<td>Field performance GEP efficacy</td>
<td>Scale and scope of testing</td>
<td>Not quite good enough</td>
</tr>
<tr>
<td></td>
<td>Ecology of the BCA and antagonist</td>
<td>A research-intensive part of the development</td>
<td>Unfavourable pathogen interactions</td>
</tr>
<tr>
<td>Full commercialisation</td>
<td>Market size and introduction</td>
<td>Partners, advisory support, publicity, pricing policy</td>
<td>Market too small to recoup development costs</td>
</tr>
</tbody>
</table>

Collinge et al 2022
Regen Spring Barley

Min till
Plough

Untreated – no fungicide
Biological – Serenade (1.0 L/ha) @GS 30. Revystar (0.5 L/ha) + Folpet (0.5L/ha) @GS 45
Elicitor - Laminarin (0.75 L/ha) @GS 30. Revystar (0.5L/ha) +Folpet (0.5L/ha) @GS 45
T2 fungicide only – Revystar XE (1.0 L/ha) + Folpet (1.0L/ha) @GS 45
T1+T2 fungicides – Ascra X Pro (0.6 L/ha) + Folpet (0.75L/jha) at GS 30. Revystar (0.75L/ha)+folpet (0.75L/ha) @GS45
Regen Spring Barley - 2023

Yield (t/ha)

- Min Plough
- Plough
Regen Spring Barley – 2023 Fusarium

*Fusarium* detected in stem base tissue of barley
No symptoms of infection/disease
Not detected in corresponding soil samples

D = direct drill
P = plough
F = Fallow
M = Mustard
R = Radish
V = Vetch

Non-inversion tillage = increased Fusarium risk?
Acknowledgements

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Thank you for your attention

Submit an abstract for CPNB 2024 - Association of Applied Biologists (aab.org.uk)