The economics of managing fungal diseases

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A Conceptual Framework for Economic Management of Foliar Fungal Pathogens

IDM

$$$

seed
treatment
cultivation
proximity
in crop fungicides

weeds
variety
rotation
crop residue management
Fungicide Sales in Australia

variable with an average increase of $4.5M per year
includes plant growth regulants
includes broadacre agriculture and horticulture
Source ABARES: ACS2014_FarmInputsTables_v1.0.0 Table 87
Coefficient of variation of yield of wheat
1998-2012

Overview

• Aim: strategies for economical ways of prolonging useful life of fungicides and resistance cultivars
• Wheat industry trends: area planted; yields, prices, fungicide sales
• Improving decisions with focus on return on investment to fungicides;
• Q: Does prophylaxis (insurance) application (preventative) of foliar fungicides (FFs) in G31-G39 always return a positive return on investment?
  – Why, for whom, how, when, where, what.
  – How can we get a +ve and high ROI to FFs.
  – What are the chances of a +ve ROI to foliar fungal chemical @ G31+
  – Which factors are more important: price, cost, probability of season type, likelihood of disease severity;
• A: Yes, but only
  – in years with high likelihood of above average potential yield
  – coinciding with high to moderate disease severity.
• Use weather forecasts in Aug for Sep/Oct outlook.
• Reconcile grower and advisor anticipated outcomes and decision criteria.
• minimising maximum regrets, with small chance of high losses in high rainfall years, may bring very modest expected ROI when balance of possible season ends and disease severities are considered.
Key considerations for effective disease management in cereal crops

- understanding fungicide mode of action and the movement of fungicides in the plant;
- applying foliar fungicides by growth stage versus applying by disease threshold;
  - fungicides are the last line of defence against pathogens in IDM
  - fungicides do not create yield
  - fungicides protect a proportion of the yield potential
  - effectiveness fungicides depends on the disease pressure and the susceptibility of pathogen to the MoA.
- developing strategies based on the importance of the plant structures being protected – “money leaves”
- important role of temperature, moisture and humidity, as drivers for disease development & green leaf area retention

Decision Making Under Risk

- Identify possible sources of risk
- Identify possible outcomes that can occur from an event
- List the strategies available
- Quantify the consequences of each possible outcome
- Estimate the risk and expected returns for each strategy
- In other words define:
  - Actions – fungicide at G31, G39
  - Events – season types and disease severity scenarios
  - Payoffs – with and without fungicide
  - Probabilities - requires
    - Learning from the past and experts - frequentist view
    - Making educated guesses about future events – subjectivist view
- Criteria
  - From whose perspective and on what criteria?
Decision Rules/Criteria

• Most likely outcome and maximizing expected profit/GM
• Maximum expected value
  – Which? Yield, Price or Revenue or GM
• Max utility – accounting for risk aversion and wealth
• Risk and returns comparison
• Maximin - Largest of the minimum returns
• Minimax (for regrets): smallest maximum regret
• Safety first
  – Rule 1: Meet a stated minimum return with certain probability
  – Rule 2: Having met rule 1, maximise expected return
• Break-even probability
  – aka probability of success – e.g. probability of payback of COP
Economic Questions for Chemical Management of Foliar Fungal Pathogen during GS31-GS39 (Aug & Sep)

• Does prophylaxis (insurance) application of foliar fungicides (FFs) in G31-G39 always return a positive return on investment?
  – If not, then, why, for whom, how, when, where, and what factors play the most important role. How can we get a +ve and high ROI to FFs.

• How do we avoid costly false negative diagnoses of typical foliar fungal diseases with potentially large opportunity cost of profit foregone
  – Losing 1 t/ha @ 250 $/t over 2000 ha = $500,000 per annum?

• Lets assume grower
  – is in Katanning (MRZ: Agzone 3) growing 750 ha of wheat on a 2500 ha property;
  – Has wheat in rotation with canola and barley – wheat on wheat stubble being rare;
  – Needs to tackle multiple pathosystems - several pathogens simultaneously;
  – Motivated to practice IDM if profitable;
  – Aims to maximise profit including from IDM;
  – Reduces crop residues (stubble load) several reasons;
  – In-furrow fungicide applied;
  – Plants disease resistant cultivars of wheat;
  – Uses Tebuconozole mixed in with weed control and or liquid N at GS20;
  – Has the costs of production (~$300/ha excluding foliar fungicide GS31-GS39)
  – Disease is among several of her abiotic and biotic crop production constraints;
Flag leaf and ear contribute 65% of total yield

Target of GS31-G39 fungicide protection

Source: UK HGCA – Home Grown Cereals Authority
Value of Information.
What are the chances?

Forecasts made by DAFWA for probability of above median rainfall using data up to and including August for period Sept to Oct. Based on data from 1975-2014.
Weather, Disease & Crop Growth Stage

Pre G31

Weather Post G31

Disease Severity Post G31
Subjective probabilities of season finish scenarios and degree of disease severity in each season

<table>
<thead>
<tr>
<th>Season Finish Scenarios</th>
<th>Season Finish Probability S</th>
<th>Disease Severity</th>
<th>Disease Severity</th>
<th>Disease Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disease Prob DH</td>
<td>Joint Prob SxDH</td>
<td>Disease Prob DM</td>
</tr>
<tr>
<td>Wet</td>
<td>25%</td>
<td>35%</td>
<td>9%</td>
<td>55%</td>
</tr>
<tr>
<td>Average</td>
<td>50%</td>
<td>25%</td>
<td>13%</td>
<td>50%</td>
</tr>
<tr>
<td>Dry</td>
<td>25%</td>
<td>10%</td>
<td>3%</td>
<td>55%</td>
</tr>
<tr>
<td>Probability</td>
<td>100%</td>
<td>24%</td>
<td>53%</td>
<td>24%</td>
</tr>
</tbody>
</table>
### CCDM-IDM Decision Tree Model (Prototype Version 0.1)

#### Copyright applies

<table>
<thead>
<tr>
<th>Season to Date Condition</th>
<th>Prob of anticipated season finishing conditions</th>
<th>Anticipated season finishing conditions</th>
<th>Prob of disease severity occurrence</th>
<th>Joint prob of season &amp; disease</th>
<th>Disease severity &amp; yield</th>
<th>Gross Margin $/ha with and without fungicide and net benefit of fungicide</th>
<th>Return on investment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HighD</td>
<td>Nil Fung</td>
<td>Fung</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>nil</strong></td>
<td>Fung</td>
<td>Nil Fung</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yield loss</td>
<td>40%</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yield</td>
<td>4.98</td>
<td>3.0</td>
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</tbody>
</table>

#### Results

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>AvgS</th>
<th>WetS</th>
<th>MedD</th>
<th>LowD</th>
<th>HighD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Price $/t</td>
<td>240</td>
<td>3.30</td>
<td>2.60</td>
<td>2.00</td>
<td>2.40</td>
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<tr>
<td>COP $/ha</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exc. Later expenses</td>
<td>100%</td>
<td>50%</td>
<td>13%</td>
<td>25%</td>
<td>55%</td>
</tr>
<tr>
<td>Exp ROI to Fung</td>
<td>17%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Ben $</td>
<td>8,077</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prob of +ve ROI</td>
<td>38%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>2.60</td>
<td>2.35</td>
<td>2.08</td>
<td>2.29</td>
<td>2.29</td>
</tr>
<tr>
<td>Add Opex $/ha</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fung ($/ha)</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROI to Fung</td>
<td>-26%</td>
<td>13%</td>
<td>3%</td>
<td>9%</td>
<td>3%</td>
</tr>
<tr>
<td>GM Nil Fung ($/ha)</td>
<td>248</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM +Fung ($/ha)</td>
<td>235</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net + Fung ($/ha)</td>
<td>-12.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Net ROI</strong></td>
<td><strong>158%</strong></td>
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</tr>
<tr>
<td><strong>Exp ROI to Fung</strong></td>
<td><strong>17%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Net Ben $</strong></td>
<td><strong>8,077</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Prob of +ve ROI</strong></td>
<td><strong>38%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Assumptions

- **Yield (t/ha)**
  - **HighD**: 2.40
  - **AvgS**: 2.60
  - **MedD**: 2.35
  - **LowD**: 2.00
  - **DryS**: 2.00
  - **WetS**: 3.30

- **Add Opex $/ha**
  - **HighD**: 0
  - **AvgS**: 0
  - **MedD**: 0
  - **LowD**: 0
  - **DryS**: 0
  - **WetS**: 0

- **Fung ($/ha)**
  - **HighD**: 49
  - **AvgS**: 49
  - **MedD**: 49
  - **LowD**: 49
  - **DryS**: 49
  - **WetS**: 3.30

- **ROI to Fung**
  - **HighD**: -26%
  - **AvgS**: 13%
  - **MedD**: 3%
  - **LowD**: 9%
  - **DryS**: 9%
  - **WetS**: -10%
Expected net benefit of foliar fungicide applied after GS31

$$ENBf = D \sum_{d=1}^{m} Pd \sum_{s=1}^{n} [(Yfds - Yds) \times G - (F \times C) - A - Ws] \times Ps$$

Where:

$D$ = Size of disease affected area

$ENBf$ = Expected net benefit of foliar fungicide applied between GS31-39;

$d$ = disease severity types post GS31 (e.g. $m = 3$ cases of high, moderate and low disease severity);

$Pd$ = probability of disease severity for each of the season finish types;

$s$ = season finish type (e.g. $n = 3$ finish type being wet, average, dry);

$Ps$ = probability of season finish type;

$Yfs$ = Grain yield of cereal crop with fungicide applied for each disease and season finish scenario;

$Ys$ = Grain yield in the absence of fungicide for each disease and season scenario;

$G$ = Expected grain price;

$F$ = Rate fungicide applied per hectare;

$C$ = Cost of fungicide per unit of $F$;

$A$ = Application cost of fungicide ($/ha$) and varies by boom (contract or grower) or by aircraft;

$Ws$ = Wheeling losses in dollars per hectare where $Ws = 3\% \times Yfs \times G$, if $A$ is a boom spray.
ROI to Foliar Fungicides at GS31-39

- WetS & HighD: 268%
- WetS & MedD: 121%
- WetS & LowD: -26%
- AvgS & HighD: 28%
- AvgS & MedD: -36%
- AvgS & LowD: -62%
- DryS & HighD: 8%
- DryS & MedD: -24%
- DryS & LowD: -68%

Expected ROI = 17%
### Results

#### Scenarios for circumstances around disease and its management

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Expected Weighted Avg</th>
<th>Chance of positive</th>
<th>Expected Net Benefit</th>
<th>Max Net Benefit (Max Regret)</th>
<th>Minimum Net Benefit</th>
<th>Max Pathogen Management Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season W25,A50,L25 (Base)</td>
<td>17%</td>
<td>38%</td>
<td>$11 8,077</td>
<td>$144 108,180 -30 -22,500 54</td>
<td>40,320</td>
<td></td>
</tr>
<tr>
<td>Season W45,A45,L10</td>
<td>56%</td>
<td>53%</td>
<td>$31 23,094</td>
<td>$144 108,180 -30 -22,500 54</td>
<td>40,320</td>
<td></td>
</tr>
<tr>
<td>H wheat price ($300/t)</td>
<td>33%</td>
<td>38%</td>
<td>$21 15,722</td>
<td>$188 140,850 -30 -22,500 60</td>
<td>44,775</td>
<td></td>
</tr>
<tr>
<td>Fungicide twice the cost</td>
<td>-10%</td>
<td>23%</td>
<td>-$4 -3,173</td>
<td>$129 96,930 -45 -33,750 69</td>
<td>51,570</td>
<td></td>
</tr>
<tr>
<td>Disease more likely</td>
<td>34%</td>
<td>53%</td>
<td>$19 14,180</td>
<td>$144 108,180 -30 -22,500 54</td>
<td>40,320</td>
<td></td>
</tr>
<tr>
<td>Yld uncertain 4.0,2.5,1.5</td>
<td>20%</td>
<td>35%</td>
<td>$16 11,745</td>
<td>$181 135,900 -30 -22,500 59</td>
<td>44,100</td>
<td></td>
</tr>
</tbody>
</table>

- Don’t lose your cheap fungicide;
- Know your season;
- Look after higher yielding expensive crops;
- Manage pathogen spore load;
Profitable Integrated Disease Management

• Fungicides at G31-G39 have high ROI in years with high likelihood of above average potential yield coinciding with high to moderate disease severity.
  – Use weather forecasts in Aug for Sep/Oct outlook.
  – Reconcile grower and advisor anticipated outcomes and decision criteria.
  – Minimising maximum regrets, with small chance of high losses in high rainfall years, may bring very modest expected ROI when balance of possible season ends and disease severities are considered.

• Effective pathogen management combines strategies to:
  – Reduces pathogen population sizes
  – Matches chemical use to
    • Development stage of the crop
    • Prospect of season and potential yield
    • Prospect of infection severity – yield loss +/- chemical
  – Limits pathogen dispersal, and
  – Forces pathogens to
    • Endure fluctuating, diversifying selection forces

• These strategies have the best prospects
  – For reducing
    • The emergence of new infectivity;
    • New fungicide resistance; and
  – For limiting the evolution of increased pathogenicity.
Improving ROI to fungicides go hand in hand with reducing the rate of emergence of fung. resistance

- All fungicides exert selection pressure on the pathogen population
- Pathogens, fungicides and tactics alter the selection pressure
- Strategies for prolonging useful life of fungicides and resistance cultivars:
  - 1: Reduce rate of increase of resistant and that of the susceptible strain of pathogen
  - 2: Reduce rate of increase of resistant strain relative to rate of increase of susceptible
  - 3: Reduce exposure time to MoA at risk of resistant
- IDM works to preserve fungicides:
  - Use resistant crop cultivars
  - Use crop rotations
  - Manage summer weeds control
  - Practice crop hygiene methods including crop residue management
  - Use break-crops (rotations) and weed control
  - Minimise the dose of the failing fungicide
  - Mix the fungicide with another active ingredient
  - Alternate the fungicide with another.

Thank You
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