Fungicide Futures

Practical measures to combat fungicide resistance in pathogens of barley
The fungicide resistance challenge

Increasing barley yields in the UK over recent years have been supported by high levels of fungicide use. This usage reflects, in part, the low levels of resistance in some popular varieties and the unpredictability of disease pressure. Robust fungicide programmes have put greater selection pressure on disease pathogens, making the appearance of resistance to fungicides more likely.

Ramularia is currently of greatest concern, with significant shifts in sensitivity to strobilurins, azoles and succinate dehydrogenase inhibitors (SDHIs) in UK populations. Though good disease control can be achieved in barley by using robust fungicide programmes, it is essential to use comprehensive anti-resistance strategies to slow resistance development and preserve the efficacy of both existing and new chemistry.

How fungicide resistance happens

When fungicides are applied, susceptible fungal strains are usually controlled very effectively. However, any resistant strains present (through mutation or natural variation) are more likely to survive and reproduce. This process of ‘selection’ makes each subsequent generation more difficult to control. In the absence of any fitness costs, resistant strains may come to dominate the population, causing disease control to fail.

How to manage fungicide resistance

A good fungicide anti-resistance strategy does not need to compromise disease control. In fact, if done well, such strategies should result in robust and sustainable control. Strategies should:

- Exploit all practical, non-chemical control methods to reduce disease risk and slow epidemic development
- Limit the time over which the pathogen population is exposed to the fungicide
- Use effective mixtures and alternate fungicides with different modes of action
- Use the minimum dose required to effectively control target pathogens

Multi-sites

Fungicides that have multi-site modes of action are much less prone to resistance. The process of mutation and selection, leading to resistance, is very rarely seen with multi-sites outside the laboratory.

Non-chemical control methods

Varietal resistance to disease remains patchy, with some popular varieties having low resistance ratings. Nevertheless, where markets permit and the wider agronomy package suits, varieties with resistance to the diseases prevalent should be selected. Such varieties can be managed with fewer fungicide inputs, reducing selection pressure on fungicides. The approach also allows greater flexibility in spray timing.

Appropriate husbandry techniques can be used to reduce disease pressure and allow less intensive fungicide programmes to be used, thus reducing selection pressure.

Early sowing of spring varieties (December to February) can increase rhynchosporium pressure.

Controlling volunteers and reducing crop debris can help reduce rhynchosporium, net blotch, brown rust and mildew pressure.

Crop stress, which can be caused by some chemical applications (e.g. late season-applied morpholines), waterlogging or under-fertilisation with nitrogen, can make ramularia symptoms worse.

Seed can be a disease source for rhynchosporium and net blotch. Consequently, seed should not be saved for re-sowing from heavily infected crops.

Figure 1. Ramularia leaf spot symptoms – the ‘5Rs’: (1) Ringed with yellow margin of chlorosis, (2) Rectangular shape, (3) Restricted by the leaf veins, (4) Reddish-brown colouration, (5) Right through the leaf
Appropriate fungicide use

Fungicide programmes should be tailored to crop disease risk and take account of historic disease pressure, varietal resistance, whether it is a first or subsequent barley crop and the sowing date. A variety of modes of action are effective against most barley diseases, providing excellent scope for programmes with strong anti-resistance benefits. At some timings, the most appropriate action may be to avoid making an application.

Fungicide treatment frequency

- Each application increases the period of exposure of pathogens to fungicides. This can select for resistant strains, even if the pathogen is at a very low level in the crop
- Applications should be made in response to the disease risk on a crop-by-crop basis, taking account of regional disease pressure and varietal resistance
- On susceptible varieties, the consequences of applying too few fungicide treatments can be severe. On more resistant varieties or in lower-risk situations, the economic consequences of overtreatment or undertreatment are in closer balance. Inputs should always be matched to the risk
- T0 sprays in winter barley should only be made if overwintering disease levels are high. To minimise selection for resistance, different modes of action to those planned for later in the season should be used
- T3 sprays seldom give an economic yield benefit in barley and should not be used
- Follow statutory limits and never exceed the maximum number of applications for a product or mode of action

Fungicide timing

- Because spray timings have a significant impact on fungicide efficacy, a well-timed spray can avoid the need for higher doses or extra sprays
- Accurate timing is about applying in a protectant situation, rather than a curative/eradicant situation
- In barley, T1 sprays help preserve maximum tiller numbers ahead of significant disease ingress. T2 sprays continue this protection and protect against ramularia, to retain green leaf and maximise grain fill
- The efficacy of previous treatments should be monitored and subsequent inputs adjusted accordingly

Fungicide dose

- Evidence from wheat suggests that SDHI resistance evolves faster at higher doses, while azole resistance is less strongly affected by dose and may be more heavily driven by application number
- This relationship between dose and application number may not hold true in barley, with different diseases and different mutations driving resistance
- Use the minimum dose of azole and SDHI required for effective disease control with a robust dose of a multi-site to protect other chemistry and help slow the spread of resistance

Fungicide mixtures

- Mixtures of different modes of action, which are effective against the target pathogen, should be used to slow fungicide resistance
- Mixtures should be balanced, such that mixing partners give comparable efficacy, where possible
- Compared to wheat, there are more actives available with efficacy against some of the key target barley pathogens. Strobilurins, morpholines and cyprodinil should be considered, as well as the azole, SDHI and multi-site options
- In tank mixes, all components should have an effective mixing partner for the diseases present
- It should not be assumed that a pre-formulated mixture is balanced for resistance purposes. Although many are, not all are – it depends on the disease target. Product labels often contain relevant guidance

Fungicide alternation

- Alternating fungicides reduces the period of exposure of pathogens to any one mode of action
- In many circumstances, mixtures may provide a more practical and effective strategy than alternation and may be a legal requirement (check product labels)
- Mixing and alternating can both be practiced – it is not an ‘either/or’

Fungicide multi-sites

- Fungicides with multi-site modes of action (chlorothalonil and folpet) are at lower risk of resistance and have no recorded instances of resistance in cereal foliar diseases
- Multi-sites should be used as a cost-effective mixture partner to protect higher risk single site-acting fungicides (e.g. azoles, strobilurins and SDHIs)
- Chlorothalonil is the only mode of action with efficacy against ramularia and should be included where a T2 fungicide is applied
- All multi-sites are protectant only, so use must be timed carefully

Fungicide programmes

Resistance management should be considered throughout the spray programme.

**T0:** Consider alternatives to azoles, such as strobilurins, morpholines, cyprodinil and multi-sites

**T1:** Use mixtures with different modes of action appropriate to the diseases present

**T2:** Use mixtures with different modes of action appropriate to the diseases present. Include the multi-site chlorothalonil for ramularia control and try to alternate actives compared with the T1 spray

Additional fungicide sprays at different timings, such as autumn applications to winter barley, add selection pressure and rarely have a yield benefit.
**Fungicide Futures**

Practical measures to combat fungicide resistance in pathogens of barley

<table>
<thead>
<tr>
<th>DON'T</th>
<th>AVOID</th>
<th>DO</th>
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<tbody>
<tr>
<td><strong>Strobilurins</strong></td>
<td><strong>SDHIs</strong></td>
<td><strong>Azoles</strong></td>
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<tr>
<td>Apply more than twice to any cereal crop</td>
<td>Overexpose azoles (use alternative chemistry where possible)</td>
<td>Use azoles alone for mildew control</td>
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<td>Apply without a mixing partner</td>
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<td>Applying when disease risk does not merit it</td>
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<td>Rely on for ramularia control</td>
<td>Mix with at least an equivalent label rate of an azole or a strobilurin</td>
<td>Applying only with a multi-site as a mixing partner</td>
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<td>Make use of strobilurins to diversify fungicide programmes</td>
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<td><strong>FRAC Code 11</strong></td>
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<td>SDHI fungicides include bosalid, benovindiflupyr, bixafen, flupyradifenox, isopyraflor and penthiopyrad. They have moderate-to-strong activity against rhynchosporium, moderate activity against brown rust, and moderate activity against powdery mildew. They are classed as medium-to-high risk for the development of resistance and there is cross-resistance between different SDHIs. Although SDHI activity against net blotch has previously been strong, isolates with mutations conferring resistance to SDHIs have been detected in the UK, resulting in variable performance in trials. Ramularia isolates with strong resistance to SDHIs are now common in the UK and SDHIs can no longer be relied upon for ramularia control. Robust anti-resistance measures must be used to slow the further spread of resistance.</td>
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Building resilient and robust fungicide programmes

A pyramid of control measures can be used to protect fungicide efficacy from the foundation up.

- **SDHIs**
- **Azoles and Strobilurins**
- **Multi-sites, cyprodinil and morpholines**
- **Cultural controls**
- **Varietal resistance**

**The minimum dose and number of SDHI sprays required for effective disease control should be used**

**Azoles and strobilurins have broad spectrum activity against barley diseases but should be used in mixtures**

**These fungicides protect other modes of action and add efficacy**

**Cultural controls (e.g. sowing date, seed rate and crop hygiene) can reduce disease pressure**

**Varietal resistance provides a foundation for disease control**
Know your enemy

Keep up to date with the current resistance status of target diseases, both to ensure optimum control and that appropriate anti-resistance measures are being employed. FRAG-UK provides up-to-date information on the UK situation via its website and more general advice through its publications.

ahdb.org.uk/knowledge-library/frag

What is Fungicide Futures?

Fungicide Futures is a joint initiative between AHDB and the Fungicide Resistance Action Group UK (FRAG).

The initiative combines anti-resistance management information, developed with FRAG, and the power of AHDB’s communications channels. With a focus on practical on-farm action, Fungicide Futures promotes powerful and consistent messages on effective low resistance risk fungicide programmes to growers of cereals and their advisers.

ahdb.org.uk/knowledge-library/fungicide-futures