Fungicide Resistance Management in Cereals

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Septoria tritici on wheat

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What is resistance?

Resistance occurs when a pathogen becomes so insensitive to a fungicide that the fungicide's field performance is impaired. Resistance can arise rapidly and completely so that disease control is lost in a single step. More commonly, resistance develops gradually so that the pathogen becomes progressively less sensitive. When this happens there is usually no initial detectable loss of control.

Introduction

Fungicides, in combination with exploitation of resistant varieties and other agronomic and cultural techniques, will be the mainstay of cereal disease control for the foreseeable future and so must be protected from the threat of resistance.

Applying appropriate products at the right time and at the right dose is critical for good disease control. Poor field performance can often be attributed to cutting recommended rates of use, or to poor or mistimed application, rather than resistance. The risk of development of resistance is linked to a number of factors including the specific mode of action (MOA) of the fungicide, the biology of the target pathogen and the level of exposure of the pathogen to the fungicide. Resistance management is vital to maintain effective control whilst minimising over-exposure of the pathogen and reducing the risk of resistance developing. This risk was dramatically illustrated in 2003 when widespread resistance to strobilurin (QoI) fungicides was reported in *Septoria tritici* populations in the UK, Ireland, Germany, France and Denmark.

FRAG-UK and HGCA have previously published two leaflets on fungicide resistance, in 1996 and 2000. This new publication incorporates the many developments that have occurred since the last leaflet was issued. In particular, fungicides representing a number of new groups have been registered, which offer a greater opportunity to minimise the risk of resistance developing.

These revised guidelines include:

- up-to-date information on the resistance status and best use of each fungicide group.
- information on the following new groups of fungicides:
  - benzophenones
  - quinazolinones
  - carboxamides
  - thiophene-carboxamides
  - amidoxines

General Resistance Management Guidelines

Good resistance management is based on limiting the level of exposure of the target pathogen to the fungicide.

- Fungicide input is only one aspect of crop management and other control measures should always be used, such as good hygiene through disposal of crop debris and control of volunteers which may harbour disease.
- Always aim to select varieties exhibiting a high degree of resistance to diseases known to be prevalent in your area, in addition to the main agronomic factors you desire.
- Avoid growing large areas of any one variety, particularly in areas of high disease risk where the variety is known to be susceptible. The CropMonitor project (www.cropmonitor.co.uk) provides in-season information on seasonal and regional disease risks and on the appropriate disease management strategies for key varieties.
- Only use fungicides in situations where the risk or presence of disease warrants treatment.
- Always use the minimum effective fungicide dose.
- Make full use of effective fungicides with different modes of action in mixtures or as alternate sprays. Mixtures of eradicant fungicides with protectant materials offer the most flexibility as well as reducing resistance risk.
- Monitor crops regularly for disease and treat before the infection becomes established.
- Avoid repeated applications of the same product or mode of action and never exceed the maximum recommended number of applications to each crop for any particular fungicide group.
- When planning spray programmes, take into account any earlier use of fungicide groups as seed treatments.
- When in doubt about different resistance situations take expert advice.

Septoria leaf spot

Mycosphaerella graminicola / Septoria tritici

Introduction

Mycosphaerella graminicola (*Septoria tritici*), **is the most important foliar disease of UK winter wheat. Although some newer varieties have good resistance, fungicides have been the main means of control to avoid serious yield loss. Rainfall splashes spores from leaf to leaf, although they may also spread to the upper leaves through overlapping contact with the lower canopy.**

Resistance status

In the mid 1980s, *M. graminicola* developed resistance to benzimidazole fungicides (MBCs). Isolates resistant to QoI fungicides were first detected in 2002 and are now widespread throughout the country at high levels. Sensitivity to DMIs has declined since the mid 90s with notable increases in the frequency of resistant isolates occurring during 2003 and 2004. Data from 2005 and 2006 indicate that this may now have stabilised. Several azoles, primarily epoxiconazole and prothioconazole, continue to provide robust control even under high disease pressure.

Fungicide Groups

Resistance risk	Suggested use

Sterol demethylation inhibitors (DMIs) – Azoles

Current evidence shows a significant shift towards reduced sensitivity to DMIs. Field performance from the most effective products has still been good in recent years as long as appropriate timings and doses were used. There is now considerable variation in performance of active ingredients in this group and to ensure good performance it is important to select appropriate DMI products.

- Use in conjunction with a suitable product with multi-site activity at an effective dose to ensure a high level of disease control.
- Do not use DMIs alone. Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.

Fungicide Groups

Resistance risk	Suggested use

Quinone outside inhibitors (QoIs) – Strobilurins

Due to prevalence of the G143A mutation within the population, resistant isolates of *M. graminicola* are widespread at high levels throughout the UK. Despite this, QoIs still give some control and yield responses are still evident.

- Always apply QoI fungicides in mixture with non-cross resistant fungicides.
- Use an application rate of the partner appropriate for disease control on its own.
- Do not apply more than two sprays of a QoI-containing fungicide to any one crop.
- Useful at T3 for their 'greening effect' and for control of rusts

Chloronitriles

Chlorothalonil has been available commercially for many years with no cases of resistance recorded. Its multi-site, protectant activity makes it an ideal partner against *M. graminicola* as part of an anti-resistance strategy when mixed with DMIs or QoIs, particularly at the T0 or T1 spray timing.

- Apply preventatively in tank mix with DMIs and QoIs.
- Use appropriate doses to ensure protection of the partner fungicide.
- Do not apply alone.
- Do not apply a total dose of more than 3L/ha to a crop in a season

Dithiocarbamates

Mancozeb has also been available for many years and there have been no cases of resistance recorded in this pathogen. Considered a low risk group because of its multi-site activity.

- Apply preventatively, in mixture with other fungicide groups.
- Use as part of an anti-resistance strategy with DMIs and QoIs.

Carboxamides

Resistance known in other non-cereal pathogens (*Alternaria, Botrytis*). In the UK cereal market carboxamides are currently only available in mixture with a triazole so resistance risk is considered to be low to moderate.

- Different mode of action offers improved anti-resistance management strategy.
- Also effective against eyespot.

Powdery mildew

Blumeria graminis/Erysiphe graminis

Introduction

Powdery mildew exists as specific strains. Each one can only infect wheat, barley, oats or rye - e.g. *B. graminis tritici* attacks wheat but not other cereals. Cross-infection can occur between winter and spring-sown varieties of the same cereal species.

Resistance status

Cereal mildews have an inherently high resistance risk because of their remarkable ability to adapt to fungicide treatments. Currently, resistance in mildew to QoIs is high across Northern and Western Europe. Following an initial shift towards reduced sensitivity, the sensitivity pattern to the morpholines and DMIs has remained stable for several years, with good field performance. Isolates resistant to quinoxyfen have been found in northern Germany with reports of reduced performance in recent years.

Fungicide Groups

Resistance risk	Suggested use

Sterol demethylation inhibitors (DMIs) – Azoles

Intensive use of DMIs has led to significant loss of field performance against cereal mildew. Use in mixtures, or co-formulations, has helped to prevent further erosion of activity. Monitoring data from 2006/7 indicate that the situation is stable. Resistance risk remains high.

- Never use DMIs alone or repeatedly for mildew control.
- Always mix with a non-DMI fungicide at effective doses to ensure a high level of disease control.
- Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.

Quinone outside inhibitors (QoIs) – Strobilurins

Resistance in powdery mildew to QoI fungicides is widespread and this group should not be relied upon for control of this disease.

- Do not rely on QoI fungicides for mildew control.

Inhibitors of sterol reductase and isomerase – morpholines and spiroketalamines

A shift in sensitivity was recorded in the late 1990s, which led to a decline in field performance in Scotland. Since then, the sensitivity pattern has remained stable in all monitored countries. Field performance of products based on fungicides in this group is still good with no reported control failures. The risk of a further shift is moderate.

- Exploit the strong eradicant effect of this group as partners for other groups with limited eradicant activity.
- Always use in mixtures with fungicides with different modes of action.
- Use as an effective non-cross-resistant partner fungicide with DMIs for powdery mildew control.

Fungicide Groups

Resistance risk	Suggested use
Anilinopyrimidines	
Resistance risk not known but thought to be moderate. Anilinopyrimidines have been used on cereals since 1998 and no shifts in sensitivity have been detected.	≡ Use early in the spray programme to make the best use of the protectant activity of the fungicide against mildew. ≡ Moderate control provided if applied at first sign of disease. ≡ Use with a suitable eradicant partner for established infections.
Quinolines	
Resistance to quinoxyfen is established in the north of Germany but has stabilised recently. In the UK, frequency of occurrence of resistant strains remains low. The length of mildew control is reduced in field situations. Due to similarities in biological action with quinazolinone fungicides, as a precaution the two fungicide groups should not be used together where an alternative mode of action mildewicide is required. Risk is moderate.	≡ Apply preventatively, in mixture with other groups of fungicides before mildew is established. Will not control latent or established infections. ≡ Use with a suitable eradicant partner for established infections.
Amidoxines	
Resistance risk is currently not known but thought to be moderate.	≡ Use early in the spray programme to make the best use of the protectant activity of the fungicide against mildew.
Quinazolinones	
Resistance is not known for the quinazolinone group and the mode of action is currently unknown. Due to similarities in biological action with quinoxyfen (quinoline fungicide), as a precaution the two fungicide groups should not be used together where an alternative mode of action mildewicide is required. Risk is moderate.	≡ Apply preventatively, in mixture with other groups of fungicides before mildew is established. Will not control latent or established infections. ≡ Use with a suitable eradicant partner for established infections.
Benzophenones	
Resistance is not known for the benzophenone group. The resistance risk is unknown but thought to be moderate.	≡ Apply at GS30-32 for useful reduction of eyespot in addition to mildew control. ≡ Moderately curative for mildew when applied during the latent phase. ≡ Where possible, apply with a fungicide offering an alternative mode of action against mildew.
Fungicides with multi-site activity – sulphur, dithiocarbamates and potassium salts	
There is no evidence of resistance developing and resistance risk is low. They are relatively weak protectants offering alternative modes of action.	≡ Not reliable for mildew control if applied alone.

Wheat brown rust

Puccinia triticina

Introduction

Brown rust prefers warm temperatures and high humidity. Epidemics can develop quickly under the right conditions although severe attacks do not usually occur until late in the season.

Resistance status

Incidence and severity of wheat brown rust has been higher in recent years but performance of the DMIs has been maintained. No failure to control has been reported for the QoIs and no resistance has been found to any of the other groups.

Fungicide Groups

Resistance risk	Suggested use
Sterol demethylation inhibitors (DMIs) – Azoles	
Despite good field performance, shifts in the past in sensitivity of brown rust to DMIs indicate that a moderate to low resistance risk still exists. Monitoring data indicate that the situation is stable.	≡ Always mix with a non-DMI fungicide at effective doses to ensure a high level of disease control. ≡ Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.
Quinone outside inhibitors (QoIs) – Strobilurins	
Performance of QoI fungicides against brown rust remains good. No resistant isolates have been detected in widespread monitoring studies in Europe, confirming the fully sensitive picture. The genetic basis of the resistance to QoI fungicides (G143A) means that the risk of resistance developing in brown rust is low.	≡ Choose products known to be effective as variability in effectiveness of eradicant activity exists across the group. ≡ Use QoIs in combination with an effective partner with a different mode of action. ≡ Apply no more than two QoI-containing sprays to any crop.
Inhibitors of sterol reductase and isomerase – morpholines and spiroketalamines	
Little monitoring has been done since work in the early 1990s which showed no evidence of any shift in sensitivity. The risk of resistance developing remains medium to low.	≡ Use fungicides in this group for their eradicant effect, in mixtures with an effective fungicide with a different mode of action. ≡ When used in mixture, both partner products should be used at doses effective for disease control.

Wheat yellow rust

Puccinia striiformis

Introduction

Yellow rust is highly specialised. There are many different 'races', each of which affects a different range of varieties. New races, capable of overcoming varietal resistance, evolve frequently to make previously resistant varieties susceptible. Wherever possible, use the Variety Diversification Scheme and avoid drilling large areas of susceptible varieties to reduce the risk of yellow rust spreading on farm.

Resistance status

Incidence and disease pressure has been low in recent years but performance of DMIs has been maintained. No failure to control has been reported for the QoIs and no resistance has yet been found to the morpholines.

Fungicide Groups

Resistance risk	Suggested use
Sterol demethylation inhibitors (DMIs) – Azoles	
Despite good field performance, sensitivity shifts to DMIs in the past indicate that a moderate resistance risk still exists if robust anti-resistance strategies are not adopted. Monitoring data indicate that the situation is stable.	≡ Always mix with a non-DMI fungicide at effective doses to ensure a high level of disease control. ≡ Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.
Quinone outside inhibitors (QoIs) – Strobilurins	
The genetic basis of the resistance to QoI fungicides (G143A) means that the risk of resistance developing in yellow rust is low.	≡ Choose products known to be effective as variability in effectiveness of eradicant activity exists across the group. ≡ Use QoIs in combination with an effective partner with a different mode of action. ≡ Apply no more than two QoI-containing sprays to any crop.
Inhibitors of sterol reductase and isomerase – morpholines and spiroketalamines	
Little monitoring has been done since work in the early 1990s which showed no evidence of any shift in sensitivity. The risk of resistance developing remains low to medium.	≡ Use fungicides in this group for their eradicant effect, in mixtures with an effective fungicide with a different mode of action. ≡ When used in mixture, both partner products should be used at doses effective for disease control.

Other Cereal Rusts

Rust diseases affect other UK cereals. Barley is affected by brown rust *(P. hordei)* and yellow rust *(P. striiformis).* In oats, crown rust *(P. coronata var. avenae)* can be highly damaging. The general principles outlined for wheat yellow rust above apply for the control of all rusts, though it is important to ensure the products chosen have approval on these more minor crops.

Tan spot of wheat (DTR)

Pyrenophora tritici-repentis/ Drechslera tritici-repentis

Introduction

Until recently, tan spot has been a relatively rare disease in the UK. Caused by *Pyrenophora tritici-repentis*, the disease was first recorded in national surveys in 1987. Incidence of the disease has increased markedly in the last few years with 11% and 20% of crops affected in 2005 and 2006 respectively (although disease severity was very low). There is little information available on varietal resistance in the UK.

Resistance status

Decreased sensitivity to QoI fungicides was first detected in Sweden in 2003. The mutation was identified as F129L, which results in lower levels of resistance expression compared to the G143A mutation (which has now also been found within the pathogen population). Resistant isolates have been identified in a number of countries across Europe. Field resistance to DMI fungicides was recorded in 2005.

Fungicide Groups

Resistance risk	Suggested use
Sterol demethylation inhibitors (DMIs) – Azoles	
Reduced sensitivity to DMI fungicides recorded in other countries in 2005.	≡ Always mix with a non-DMI fungicide at effective doses to ensure a high level of disease control. ≡ Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.
Quinone outside inhibitors (QoIs) – Strobilurins	
Resistance to QoI fungicides was detected in 2003. Two mutations (F129L and G143A) have been found within populations. Previous monitoring showed that the majority of resistant isolates carried the F129L mutation, which confers partial rather than full resistance. Isolates carrying resistance mutations have been found in Sweden, Denmark and Germany. Isolates carrying the G143A mutation now dominate the population. Field performance of QoI fungicides alone is much reduced.	≡ Only use fungicides in this group in mixtures with an effective product with a different mode of action. ≡ When used in mixture, both partner products should be used at doses effective for disease control ≡ Apply no more than two QoI-containing sprays to any crop

Net blotch

Pyrenophora teres / Drechslera teres

Introduction

Incidence and severity of net blotch has declined in winter barley in recent years and the disease is rarely important in spring crops. Net blotch can occur on seed. Fungicide timing is usually critical.

Resistance status

Control has typically relied on QoIs and DMIs but resistance (F129L) to the QoI group was detected during 2004. Whilst no recent data are available, declines in sensitivity of net blotch isolates to DMIs seen in the early 1990s showed no link to reduced field performance. Disease control has remained reliable.

Fungicide Groups

Resistance risk	Resistance risk

Sterol demethylation inhibitors (DMIs) – Azoles

Though sensitivity to some DMIs has been shown to decline over time, some fluctuations have also been seen between years but it is thought that sensitivity across Europe is fairly stable. Field disease control in recent years has been good with no reported problems. Newer actives in this group have shown high levels of disease control.

- Always mix with a non-DMI fungicide at effective dose to ensure a high level of disease control.
- Alternate or mix fungicides with different modes of action in repeat spray programmes if possible.

Quinone outside inhibitors (QoIs) – Strobilurins

Resistance to QoI fungicides was detected in 2004 and the frequency of the mutation has increased in recent years. The mutation causing resistance (F129L) confers partial rather than complete resistance. Isolates carrying this mutation have been found in the UK, Belgium and France. Performance of QoI containing spray programmes against net blotch has been generally good in recent years.

- Only use fungicides in this group in mixtures with an effective product with a different mode of action.
- When used in mixture, both partner products should be used at doses effective for disease control
- Apply no more than two QoI-containing sprays to any crop.

Anilinopyrimidines

Resistance risk unknown but thought to be moderate. Also active against eyespot, mildew and *Rhynchosporium*.

- Use in tank mix with other products as a mixture partner with a different mode of action.

Rhynchosporium

Rhynchosporium secalis

Introduction

Rhynchosporium, **or barley leaf blotch, is a major disease of both winter and spring barley. The disease is spread mainly by rain-splashed spores and is particularly severe in the wetter parts of the UK and coastal areas.**

Resistance status

Variability in sensitivity to DMIs has been recorded for many years with some of the older actives no longer offering effective control. However, many of the newer chemicals in this group give very good control. Recent monitoring showed no shift in sensitivity with good disease control across Europe. Performance of the QoI fungicides remains good. However, risk of resistance development to QoIs in the future remains significant. Resistance to benzimidazoles (MBCs) is common and widespread in the UK.

Fungicide Groups

Resistance risk	Suggested use
Sterol demethylation inhibitors (DMIs) – Triazoles	
Though sensitivity to some DMIs has been shown to decline over time, some fluctuations have also been seen between years but it is thought that sensitivity across Europe is fairly stable. Newer actives in this group have shown high levels of disease control.	≡ Always mix with a non-DMI fungicide at effective doses to ensure a high level of disease control. ≡ Alternate or mix fungicides with different modes of action in repeat spray programmes.
Sterol demethylation inhibitors (DMIs) – Imidazoles	
While imidazoles have the same mode of action as triazoles, extensive monitoring has shown a low level of cross-resistance between them. Consequently, resistance risk is low.	≡ Ideally apply in formulated mixtures with fungicides with a different mode of action. ≡ Use no more than two applications in a season.
Quinone outside inhibitors (QoIs) – Strobilurins	
While the risk of resistance is thought to be moderate, monitoring data for 2006 shows the population is still fully sensitive and that performance of QoI containing spray programmes remains good.	≡ Select QoIs showing a high level of control as variability in activity against *Rhynchosporium* exists across the group. ≡ Always use in mixture with a fungicide having a different mode of action. ≡ Apply no more than two QoI-containing sprays to any crop.

Fungicide Groups

Resistance risk	Suggested use
Chloronitriles	
Because of the multi-site, protectant activity of chlorothalonil, the only member of this group, resistance risk is believed to be low. Chlorothalonil is not effective once an epidemic is established.	≡ Do not apply alone. ≡ Use as a mixture partner with other fungicides before the onset of serious disease. ≡ Do not apply a total dose of more than 3 litres/ha to a crop in a season.
Anilinopyrimidines	
Resistance risk unknown but thought to be moderate. There has been no evidence of any changes in sensitivity to date.	≡ Activity against *Rhynchosporium* makes fungicides in this group a good partner with alternative mode of action for tank mixes with other products. ≡ Also active against eyespot, mildew and net blotch, but weak against brown rust.
Inhibitors of sterol reductase and isomerase – morpholines and spiroketalamines	
The risk of resistance is low and there is no evidence of any change in sensitivity.	≡ Use in mixture with effective fungicides having different modes of action. ≡ Spiroketalamines are useful partner products with activity against *Rhynchosporium*
Carboxamides	
Resistance known in other non-cereal pathogens (*Alternaria, Botrytis*). In the UK cereal market carboxamides are currently only available in mixture with a triazole so resistance risk is considered to be low to moderate.	≡ Different mode of action offers improved *Rhynchosporium* control over partner triazole alone.

Eyespot

Oculimacula species

Introduction

Two species of fungi, *Oculimacula yallundae* and *O. acuformis*, cause eyespot in cereals. Symptoms caused by either species can only be distinguished by laboratory analysis. Both species attack wheat and barley but rye is affected mainly by *O. acuformis*, which, since the 1980s, is now the more common of the two.

Resistance status

Reduced sensitivity to prochloraz has been known in parts of Europe for several years. Several triazoles, particularly some of the very new fungicides, show control equivalent to anilinopyrimidines, but cross-resistance is known in this group and strains resistant to some fungicides have been found. There is no evidence of any change in sensitivity to anilinopyrimidines or QoIs.

Fungicide Groups

Resistance risk	Suggested use
Sterol demethylation inhibitors (DMIs) – Triazoles	
Little evidence to date of reductions in sensitivity to the more active triazoles with some new fungicides (e.g. prothioconazole) showing activity equivalent to anilinopyrimidines. Resistance to flusilazole in France indicates that the risk should continue to be considered moderate.	≡ Use a triazole with very good eyespot activity if risk of disease is high.
Sterol demethylation inhibitors (DMIs) – Imidazoles	
Isolates of the eyespot fungus with reduced sensitivity to prochloraz were found in Northern France in the 1990s. This led to reduced field performance. Only moderate activity against *O. acuformis*.	≡ Can provide useful control when applied at the T1 timing.

Fungicide Groups

Resistance risk	Suggested use
Anilinopyrimidines	
Risk is not known, but thought to be moderate. Although there are reports of reduced sensitivity to cyprodinil in isolates of both *O. yallundae* and *O. acuformis*, there is no evidence of any shifts in field performance. The product has now been used for several years on UK cereals.	≡ Apply at GS 30-32 as a protectant ≡ Use at doses appropriate for effective eyespot control. ≡ Determine precise timing according to disease severity and seasonal weather conditions. ≡ A good partner with alternate mode of action in tank mix with other products. ≡ Also active against *Rhynchosporium*, powdery mildew and net blotch, but weak against brown rust.
Carboxamides	
Resistance known in other non-cereal pathogens (*Alternaria, Botrytis*). In the UK cereal market carboxamides are currently only available in mixture with a triazole so resistance risk is considered to be low to moderate.	≡ Use at T1 gives good eyespot control in wheat and barley.
Benzophenones	
Risk is currently unknown.	≡ Useful eyespot control ≡ Low doses used for mildew control may not be sufficient for effective eyespot control. ≡ Good partner fungicide where powdery mildew is also a problem.

Fungicide Groups for disease control in wheat

Fungicide Groups	FRAC Mode of Action Code	Chemical Families	Common name of active substance	Examples of products with active substances	
				Alone	In Mixtures
DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	3	Imidazole	Prochloraz	Prospero	Agate
		Triazole	Bromuconazole	Jazz	-
			Cyproconazole	Caddy 240 EC	Cherokee
			Difenoconazole	Plover	-
			Epoxiconazole	Opus	Eclipse
			Fenbuconazole	-	Graphic
			Fluquinconazole	Sahara	Foil
			Flusilazole	Genie 25	Charisma
			Flutriafol	Consul	Argon
			Metconazole	Caramba	-
			Propiconazole	Bumper 250 EC	Cherokee
			Prothioconazole	Proline	Prosaro
			Tebuconazole	Folicur	Prosaro
			Triadimenol	Bayfidan	Baytan Secur
			Triticonazole	-	Kinto
Amines ("Morpholines") (SBI: Class II)	5	Morpholine	Fenpropimorph	Corbel	Eclipse
		Piperidine	Fenpropidin	Instinct	
		Spiroketalamine	Spiroxamine	Torch Extra	Helix
Carboxamides	7	Oxathiin carboxamide	Carboxin	-	Anchor
		Pyridine carboxamide	Boscalid	-	Tracker
QoI-fungicides (Quinone outside Inhibitors)	11	Oxazolidinedione	Famoxadone	-	Medley
		Strobilurin	Azoxystrobin	Amistar	Amistar Opti
			Dimoxystrobin	-	Swing Gold
			Fluoxastrobin	-	Fandango
			Kresoxim-methyl	-	Allegro
			Picoxystrobin	Galileo	Credo
			Pyraclostrobin	Comet	Envoy
			Trifloxystrobin	Twist	Sphere
Thiophene-carboxamides	38	Thiophene-carboxamide	Silthiofam	Latitude	-
AP-fungicides (Anilino-Pyrimidines)	9	Anilino-pyrimidine	Cyprodinil	Unix	Radius
Quinolines	13	Quinoline	Quinoxyfen	Fortress	Orka
PP-fungicides (PhenylPyrroles)	12	Phenylpyrrole	Fludioxonil	Beret Gold	Beret Multi
Dicarboximides	2	Dicarboximide	Iprodione	Rovral Flo	-
Benzo-thiadiazole BTH	P1	Benzothiadiazole	Acibenzolar-S-methyl	Bion	-

Fungicide Groups	FRAC Mode of Action Code	Chemical Families	Common name of active substance	Examples of products with active substances	
				Alone	In Mixtures
MBC-fungicides (Methyl Benzimidazole Carbamates)	1	Benzimidazole	Carbendazim	Tripart Defensor FL	Contrast
			Fuberidazole	-	Baytan Secur
		Thiophanate	Thiophanate-methyl	Cercobin WG	-
Amidoxines	U6	Phenyl-acetamide	Cyflufenamid	Cyflamid	-
Quinazolinones	U7	Quinazolinone	Proquinazid	Talius	-
Benzophenones	U8	Benzophenone	Metrafenone	Flexity	Capalo
Inorganics - carbonates	NC	Inorganic	Potassium hydrogen carbonate	Potassium Hydrogen Carbonate	-
Inorganics - copper	M1	Copper	Cupric ammonium carbonate	Croptex Fungex	-
Inorganics - suphur	M2	Sulphur	Sulphur	Microthiol Special	-
Dithiocarbamates and relatives	M3	Dithiocarbamate	Mancozeb	Quell Flo	Guru
			Maneb	Trimangol WDG	-
			Thiram	-	Anchor
			Ziram	AAprotect	-
Chloronitriles (phthalonitriles)	M5	Phthalonitrile	Chlorothalonil	Bravo 500	Amistar Opti
Guanidines	M7	Guanidine	Guazatine	Ravine	-

For a constantly updated version of this table, see the on-line output at http://frag.csl.gov.uk/cropspecific.cfm

Fungicide Groups for disease control in barley

Fungicide Groups	FRAC Mode of Action Code	Chemical Families	Common name of active substance	Examples of products with active substances	
				Alone	In Mixtures
DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	3	Imidazole	Imazalil	Sphinx	Robust
			Prochloraz	Poraz	Mirage Super 600 EC
		Triazole	Bromuconazole	Jazz	-
			Cyproconazole	Caddy 240 EC	Cherokee
			Epoxiconazole	Opus	Opus Team
			Fluquinconazole	-	Foil
			Flusilazole	Genie 25	Medley
			Flutriafol	Impact	Beret Multi
			Metconazole	Caramba	-
			Propiconazole	Bumper 250 EC	Cherokee
			Prothioconazole	Proline	Fandango
			Tebuconazole	Raxil	Draco
			Triadimenol	Bayfidan	Baytan Secur
			Triticonazole	-	Kinto
Amines ("Morpholines") (SBI: Class II)	5	Morpholine	Fenpropimorph	Corbel	Jenton
		Piperidine	Fenpropidin	Instinct	-
		Spiroketalamine	Spiroxamine	Torch Extra	Helix
Carboxamides	7	Oxathiin carboxamide	Carboxin	-	Anchor
		Pyridine carboxamide	Boscalid	-	Venture
QoI-fungicides (Quinone outside Inhibitors)	11	Oxazolidinedione	Famoxadone	-	Medley
		Strobilurin	Azoxystrobin	Amistar	Amistar Opti
			Fluoxastrobin	-	Fandango
			Kresoxim-methyl	-	Asana
			Picoxystrobin	Galileo	Acanto Prima
			Pyraclostrobin	Vivid	Jenton
			Trifloxystrobin	Swift SC	Jaunt
Thiophene-carboxamides	38	Thiophene-carboxamide	Silthiofam	Latitude	-
AP-fungicides (Anilino-Pyrimidines)	9	Anilino-pyrimidine	Cyprodinil	Kayak	Radius
Quinolines	13	Quinoline	Quinoxyfen	Fortress	Orka
PP-fungicides (PhenylPyrroles)	12	Phenylpyrrole	Fludioxonil	Beret Gold	Beret Multi
Dicarboximides	2	Dicarboximide	Iprodione	Rovral Flo	-
MBC-fungicides (Methyl Benzimidazole Carbamates)	1	Benzimidazole	Carbendazim	Delsene 50 Flo	Contrast
			Fuberidazole	-	Baytan Secur

Fungicide Groups	FRAC Mode of Action Code	Chemical Families	Common name of active substance	Examples of products with active substances	
				Alone	In Mixtures
Benzotriazines	35	Benzotriazine	Triazoxide	-	Raxil S
Amidoxines	U6	Phenyl-acetamide	Cyflufenamid	Cyflamid	-
Quinazolinones	U7	Quinazolinone	Proquinazid	Justice	-
Benzophenones	U8	Benzophenone	Metrafenone	Attenzo	Capalo
Inorganics - carbonates	NC	Inorganic	Potassium hydrogen carbonate	Potassium Hydrogen Carbonate	-
Inorganics - copper (different salts)	M1	Copper	Cupric ammonium carbonate	Croptex Fungex	-
Inorganics - suphur	M2	Sulphur	Sulphur	Solfa WG	-
Dithiocarbamates and relatives	M3	Dithiocarbamate	Mancozeb	Trimanzone	-
			Maneb	Trimangol WDG	-
			Thiram	-	Anchor
			Ziram	AAprotect	-
Chloronitriles (phthalonitriles)	M5	Phthalonitrile	Chlorothalonil	Bravo 500	Amistar Opti
Guanidines	M7	Guanidine	Guazatine	Ravine	Panoctine Plus

For a constantly updated version of this table, see the on-line output at http://frag.csl.gov.uk/cropspecific.cfm

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The Fungicide Resistance Action Group - UK (FRAG-UK) was formed in 1995 to look at fungicide resistance issues and to publish information and advice relevant to the UK. The group combines the expertise of industry with the independent sector to produce straightforward, up-to-date information on the resistance status of important diseases in UK agriculture and to suggest ways of combating resistance once it has occurred.

This leaflet and further information on resistance are available at http://www.pesticides.gov.uk/rags.asp?id=644

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