

MEMBERSHIP

The working group is comprised of the following members:

Andy Leadbeater (new chairman appointed 30-11-2004)	Syngenta
Helge Sierotzki	Syngenta
Paul Varney	Syngenta
Karl-Heinz Kuck	BayerCropScience
Andreas Mehl	BayerCropScience
Albert Witzemberger	BayerCropScience
Friedrich Kerz-Moehlendick	BayerCropScience
Pierre Begel	DuPont
Andy Selley	DuPont
Jean-Luc Genet	DuPont
Gerd Stammler	BASF
Kristin Klappach	BASF
Karl-Heinz Lorenz (leaving 2005)	BASF
Ulrich Schöfl	BASF
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INTRODUCTION

The working group is responsible for global fungicide resistance strategies in the Qo inhibitor fungicides (QoI). The Qo inhibitor fungicides (QoI) all act at the Quinone 'outer' (Qo) binding site of the cytochrome bc1 complex.

The QoI fungicides are: azoxystrobin, famoxadone, fenamidone, kresoxim-methyl, picoxystrobin, pyraclostrobin, trifloxystrobin, fluoxastrobin, metominostrobin, orysastrobin, dimoxystrobin and enestroburin.

They are all in the same cross-resistance group and should be managed accordingly.

[Qil fungicides act at the Quinone "inside" \(Qi\) binding site of the same complex. The only fungicide commercially available is cyazofamid.](#)

[Extensive studies have shown that although these two groups of fungicides act at the same enzyme, there has been no cross resistance detected in target pathogens, probably because the binding sites are sufficiently distinct.](#)

[Research has been carried out indicating that these two fungicide groups can both activate alternative oxidase \(AOX\) in fungi belonging to the ascomycetes. Although it is easy to demonstrate under in vitro conditions that AOX can lower the fungicide sensitivity, it is difficult to demonstrate significant AOX effects under field conditions. Probably, the alternative respiration pathway can not produce enough energy equivalents in order to allow the survival of plant pathogens during their pathogenic state.](#)

[Moreover, there is no evidence showing that the induction of the alternative respiration facilitates the occurrence of target site mutations under field conditions.](#)

[Oomycetes \(which are not true fungi\) are the only pathogen group where both QoI fungicides and Cyazofamid, are active. Studies on the role of AOX in Oomycetes are not available.](#)

[Therefore, evaluating the available knowledge, the practical relevance of AOX on the resistance risk of oomycete pathogens is considered low by FRAC](#)

[FRAC's primary concern is with the risk and management of field resistance, and considers that in terms of these considerations the QoI and Qil clearly fall within two different resistance groups \(i.e. 11 and 21 respectively\), and may be used together in effective disease control programmes.](#)

[To ensure the long-term effectiveness of all fungicides, measures to counteract the possible occurrence of resistance should be put in place. Therefore for both groups of fungicides it is recommended that effective resistance management strategies are utilised, for example the use of effective mixtures or alternation partners.](#)

Companies participating in the meetings:

BASF, Bayer CropScience, DuPont, Syngenta

**QoI working group of FRAC
Minutes of the meetings
Cereal part: on October 5th, 2004
Non-cereal part: on November 30th, 2004
Both organised by Syngenta at Badenweiler / Germany
Updated 2004 final information – Teleconference June 2nd 2005**

1. Agenda
- 1.1. Review of sensitivity monitoring
 - Cereals
 - Vines
 - Pome fruit
 - Cucurbits
 - Potato/tomato
 - Other crops
- 1.2. Review of global guidelines
- 1.2. Communication plans

2. Minutes of discussions

2.1. Review of sensitivity monitoring

2.1.1. Cereal diseases

Powdery mildew (*Erysiphe graminis* f.sp. *tritici*), wheat

Bayer CropScience

No resistance was detected in Italy. Low levels have been found in Czech Republic, Hungary and Austria while higher levels were detected in Poland.

Powdery mildew (*Erysiphe graminis* f.sp. *hordei*), barley

Bayer CropScience

Further increase in the frequency of the G143A mutation was observed in 2004 compared to 2003.

High resistance levels were found in France, Belgium and Northern D. Medium and heterogeneous levels have been found in the UK and in Western Germany. Low frequencies were detected in DK, Czech Republic and Austria. No resistance was found in 2004 in Hungary, Poland, Italy and Sweden.

Septoria leaf spot (*Septoria tritici*), wheat

BASF, Bayer CropScience, Syngenta

Extensive monitoring programmes were carried out throughout the wheat growing areas of Europe in 2004. As in previous years samples have been taken in winter, early spring and during summer.

Disease pressure in 2004 was heterogeneous in Europe in 2004, generally moderate to high (Northern Germany) and the onset of disease was early.

Frequency of resistance has further increased in wheat growing countries in Europe. Higher levels were found at sites where resistance has been previously detected and new locations were added.

Status at the end of the season 2004 is as follows:

Ireland, UK: widespread all over the countries at high levels

France: heterogeneous populations with decreasing gradient from North to South, i.e. high resistance levels in the North (Pas de Calais, Picardie) and nil to low in the South

Germany: high levels in the North (e.g. Schleswig-Holstein, Mecklenburg-Vorpommern, Niedersachsen), low or no resistance in the South (e.g. Bavaria, Baden-Wuerttemberg)

Belgium, The Netherlands, Denmark, Sweden: widespread all over the countries at high levels

Eastern Europe (Czech Republic, Poland, Lithuania, Latvia): limited data show heterogeneous picture. Low to high levels were detected in Poland; no or low resistance in other countries.

Despite the findings above field performance of spray programmes with QoI containing products was good in 2004 when FRAC guidelines have been followed.

Brown rust (*Puccinia recondita*), wheat

BASF, Bayer CropScience, Syngenta

Performance of QoI fungicides against brown rust was good. No resistant isolates were detected from widespread monitoring studies in Europe in 2004, confirming the fully sensitive picture already established.

Net blotch (*Pyrenophora teres*), barley

BASF, Bayer CropScience, Syngenta

Performance of QoI containing spray programmes against net blotch in 2004 was good.

As mentioned in the previous meeting minutes, data for the season 2003 were not available at the time of the meeting. During 2004 a few isolates from the 2003 season were found to have atypical responses (Northern France). The G143A mutation was not detected. Methodology development to detect the F129L mutation confirmed the presence of F129L mutation in single isolates in autumn 2004. As already observed with other pathogens resistance factors are significantly lower in comparison with the G143A mutation.

In 2004 resistant isolates were confirmed in France and detected for the first time in UK and Belgium; a single resistant isolate was found in South West Germany. Only the F129L mutation has been identified. [Further characterisation of these isolates has shown clear dose responses to QoI fungicides.](#) As field performance of QoI containing mixtures was good in 2004 ([experience so far during 2005 confirms this](#)) their use will remain essential in the future.

Leaf scald (*Rhynchosporium secalis*), barley

BASF, Bayer CropScience, Syngenta

Performance of QoI fungicides against leaf scald was good. Monitoring data from [2003 and 2004](#) showed a fully sensitive picture for [England, Scotland, Ireland, Germany and France.](#)

Tan spot (*Pyrenophora tritici-repentis*), wheat

[Syngenta, Bayer CropScience, BASF](#)

[Samples taken in middle Sweden in 2003 after continuous use of solo QoI since 1998 at low rates have shown decreased sensitivity. The F129L mutation was identified but not the G143A mutation. Resistance factors are significantly lower compared to the G143A mutation.](#)

[Field performance at the sites sampled in 2003 was reduced but the use of mixtures in 2004 has resulted in good disease control at the same locations. In 2004 resistant isolates were confirmed in Sweden, and detected for the first time in Denmark and Northern Germany. In the majority of these isolates the F129L mutation was detected. However, in a very few isolates in Denmark \(2\) and Germany \(3\) the G143A mutation has been detected. Further investigation of isolates is required to interpret these data.](#)

[As field performance of QoI containing mixtures was good in 2004 \(experience so far during 2005 confirms this\) their use will remain essential in the future.](#)

Microdochium nivale, wheat

Bayer CropScience

Limited data (Germany) from 2004 show a completely sensitive picture.

2.1.2. Vine diseases

Downy mildew (*Plasmopara viticola*)

BASF, Bayer CropScience, DuPont, Syngenta

In 2004, disease pressure was medium to high in the main grape growing areas of Europe.

All companies carried out major monitoring programmes in 2004 in France, Italy, Germany, Austria, Switzerland, Spain and Portugal. Both semi-quantitative bioassay and PCR techniques were used to generate data. A frequency of 1-2% G143A identified through PCR diagnosis was usually reflected as a resistant phenotype in bioassay tests.

For the first time resistant strains could be found in Austria at low levels. Compared to previous years resistance levels have stabilised at reported levels in France, Italy, Spain, Germany and Switzerland. Based on very limited sample numbers no resistance was detected in Portugal in 2004.

No performance complaints have been received. Where FRAC guidelines were followed field performance of QoI containing spray programmes was good across Europe.

Powdery mildew (*Uncinula necator*)

Bayer CropScience, Syngenta, BASF

Disease pressure was medium to high across Europe and low in the USA. In commercial use where recommended spray programmes were followed, performance of QoI containing spray programmes was very good. No complaints were received.

USA: The G143A mutation was detected in samples of *U. necator* originating from trial sites in Pennsylvania and New York, located in areas where reduced field performance of QoI fungicides was reported previously.

Additional studies are being planned to further investigate the detected resistance.

Europe: In 2003 no resistance was detected. In 2004 full sensitivity was reported based on available monitoring data including samples from France, Italy, Germany, Austria, Switzerland, Spain and Portugal.

2.1.3 Pome fruit diseases

Apple scab (*Venturia inaequalis*)

BASF, Bayer CropScience

Disease pressure was medium across Europe.

When following FRAC recommendations performance of QoI containing fungicide programmes was good.

Monitoring was carried out in Germany, France, Italy, UK, Netherlands, Belgium, Switzerland, the Czech Republic, Poland, Hungary, Spain, South Africa, Greece, USA, Japan and Chile. Employed methods included QPCR and DHPLC.

Target site mutants (G143A) were found for the first time in Chile. Following a more intense monitoring in Europe cases of resistance have been detected in regions which were not previously included in monitoring studies. However where resistance was reported in previous years the situation seems to be stable. It is important to state that resistant populations are still locally restricted to certain orchards in affected apple growing regions.

2.1.4. Cucurbit diseases

Powdery mildew (*Sphaerotheca fuliginea*) / Downy mildew (*Pseudoperonospora cubensis*)

No data generated in 2004

Resistance is known to occur in major cucurbit growing regions globally and field performance in these countries has been reduced.

2.1.5. Potato/tomato diseases

Late blight (*Phytophthora infestans*)

Bayer CropScience, DuPont

No resistance was detected in all isolates collected from potato crops in France, Germany, Netherlands, UK, Eire, Belgium, Italy, Portugal and Poland. Performance remains good.

Syngenta

Data were presented involving the use of azoxystrobin as a soil treatment targeted at *Rhizoctonia solani* and its impact on *P. infestans*. This application is considered to have a low impact on *P. infestans* and does not need to be included in the resistance management strategy of the strobilurins against potato late blight. (Information after the meeting: This position was supported in the recent FRAG-UK meeting held Dec. 2nd)."

Early blight (*Alternaria solani*)

Syngenta

In Brazil a routine monitoring programme revealed a fully sensitive picture in tomatoes and potatoes. In potatoes in the USA isolates carrying the F129L mutation were confirmed in 2004 in Nebraska, North Dakota, Wisconsin and detected for the first time in Minnesota. Resistance factors were confirmed to be low.

Field performance was good for QoI containing fungicide programmes.

2.1.6. Other crops

Strawberries

Resistant isolates of *Glomerella cingulata* have been detected in the Saga prefecture in Japan, possessing the G143A mutation (publ. Ishii, 2004).

Tree crops

In pistachios resistant isolates of *Alternaria* spp. have been detected in California / USA and found to have the G143A mutation (publ. Zhonghua Ma et al., 2003). Also in almonds resistance to *Alternaria alternata* was found in California / USA.

Further known cases of QoI resistance: [pdf hyperlink](#)

2.2. Review of global guidelines

2.2.1 Strategies and Guidelines for the 2005 season

Strategies for the management of QoI fungicide resistance, in all crops, are based on the statements listed below. These statements serve as a fundamental guide for the development of local resistance management programs.

Resistance management strategies have been further enhanced in order to be proactive and to prevent the occurrence of resistance to QoI fungicides developing in other areas and pathogens. Specific guidelines by crop follow the **general guidelines** given here.

A fundamental principle that must be adhered to when applying resistance management strategies for QoI fungicides is that:

The QoI fungicides (azoxystrobin, famoxadone, fenamidone, kresoxim-methyl, picoxystrobin, pyraclostrobin, trifloxystrobin, fluoxastrobin, dimoxystrobin, metominostrobin orysastrobin and enestroburin) are in the same cross-resistance group.

- Fungicide programs must deliver effective disease management. Apply QoI fungicide based products at effective rates and intervals according to manufacturer's recommendations. Effective disease management is a critical component to delay the build-up of resistant pathogen populations.
- The number of applications of QoI fungicide based products within a total disease management program must be limited whether applied straight or in mixtures with other fungicides. This limitation is inclusive to all QoI fungicides. Limitation of QoI fungicides within a spray programme provides time and space when the pathogen population is not influenced by QoI fungicide selection pressure.
- A consequence of limitation of QoI fungicide based products is the need to alternate them with effective fungicides from different cross-resistance groups.
- QoI fungicides, containing only the solo product, should be used in single or block applications in alternation with fungicides from a different cross-resistance group. Specific recommendation on size of blocks is given for specific crops.
- QoI fungicides, applied as tank mix or as a co-formulated mixture with an effective mixture partner, should be used in single or block applications in alternation with fungicides from a different cross-resistance group. Specific recommendations on size of blocks are given for specific crops.
- Mixture partners for QoI fungicides should be chosen carefully to contribute to effective control of the targeted pathogen(s). The mixture partner must have a different mode of action, and in addition it may increase spectrum of activity or provide needed curative activity. Use of mixtures containing only QoI fungicides must not be considered as an anti-resistance measure. Where local regulations do not allow mixtures, then strict alternations with non-cross resistant fungicides (no block applications) are necessary.
- An effective partner for a QoI fungicide is one that provides satisfactory disease control when used alone on the target disease.
- QoI fungicides are very effective at preventing spore germination and should therefore be used at the early stages of disease development (preventive treatment).

2.2.2 Specific Crop/Pathogen guidelines

2.2.2.1. Strategies and Guidelines for cereals, 2005 season

Where the new guidelines for the season 2004 were followed field performance of QoI containing spray programmes was good. It continues to be essential to use non-crossresistant mixture partners (e.g. SBIs, multisites) to ensure robust disease management. This will also help to delay the evolution of resistance especially in regions with no resistance or where resistance is at low levels.

Therefore the recommendations for the season 2005 remain unchanged.

Guidelines for using QoI fungicides on cereal crops

1. Apply QoI fungicides always in mixtures with non-cross resistant fungicides to control cereal pathogens. At the rate chosen the respective partner(s) on its/ their own has/ have to provide effective disease control. Refer to manufacturers recommendations for rates.
2. Apply a maximum of 2 QoI fungicide containing sprays per cereal crop. Limiting the number of sprays is an important factor in delaying the build-up of resistant pathogen populations.
3. Apply QoI fungicides according to manufacturers recommendations for the target disease (or complex) at the specific crop growth stage indicated.
4. Apply the QoI fungicide preventively or as early as possible in the disease cycle. Do not rely only on the curative potential of QoI fungicides.
5. Split / reduced rate programmes, using repeated applications, which provide continuous selection pressure accelerate the development of resistant populations and therefore must not be used.

2.2.2.2 Vine diseases

Guidelines for using QoI fungicides on vines

Powdery mildew (*Uncinula necator*)

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Apply a maximum of 3 QoI fungicide containing sprays per vine crop, solo or in mixture with effective mixture partners from different cross-resistance groups.
3. For table grapes, a maximum of 4 QoI fungicide containing sprays per crop may be used when 12 or more fungicide applications are made.
4. Apply QoI fungicides preventively.
5. Apply QoI fungicides in single or block application in alternation with fungicides from a different cross-resistance group.

Downy mildew (*Plasmopara viticola*)

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Apply QoI fungicides preventively.
3. Apply a maximum of 3 QoI fungicide containing sprays per vine crop, only in mixture with effective partners from different cross-resistance groups.
4. Apply QoI fungicides in single or block application in alternation with fungicides from a different cross-resistance group.

2.2.2.3 Pome fruit diseases

Guidelines for using QoI fungicides on pomefruit

Apple scab (*Venturia inaequalis*)

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated and adapted to size of trees. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. QoI fungicides must be applied only in mixture with partners contributing to the effective control of the target pathogens.
3. Apply QoI fungicides preventatively. Under high disease pressure the spray interval should not exceed 7-10 days.
4. Apply a maximum of 3 QoI containing sprays per crop. A maximum of 4 QoI fungicide applications may be used where 12 or more applications are made per crop.
5. A maximum of 2 consecutive QoI fungicide sprays is preferred. Where field performance was adversely affected apply QoI containing fungicides in mixtures in strict alternation with fungicides from a different cross-resistant group.

2.2.2.4 Potato and tomato diseases

Guidelines for using QoI fungicides on potatoes and tomatoes

Late blight (*Phytophthora infestans*)

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Where QoI fungicide products are applied alone do not exceed 1 spray out of 3 with a maximum of 3 sprays per crop. Do not use more than 2 consecutive applications.
3. Where QoI fungicide products are applied in mixtures (co-formulations or tank mixes) do not exceed 50% of the total number of sprays or a maximum 6 QoI fungicide applications whichever is the lower. Do not use more than 3 consecutive QoI fungicide containing sprays.

Early blight (*Alternaria solani*)

1. Where QoI fungicide products are applied solo do not exceed 33% of the total number of sprays or a maximum of 4. Where mixtures (co-formulations or tank mixes) are used do not exceed 50% of the total number of sprays or a maximum of 6 QoI fungicide applications, whichever is the lower.

2.2.2.5 Guidelines for using QoI fungicides on soybean diseases

QoI fungicides effectively control soybean diseases including rust, which is a major disease in Latin America and has been detected recently in the USA. There is limited experience at this point in time in terms of resistance risk. Fungicide manufacturers have initiated baseline and monitoring studies.

In order to ensure sustainable use of QoIs the Working Group recommends:

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Use QoIs preventatively or as early as possible in the disease cycle.
3. Use QoIs preferably in mixtures with fungicides from a different cross-resistance group. At the rate chosen each partner on its own has to provide effective disease control. Refer to manufacturers' recommendations for rates.

2.2.2.6 Cucurbit diseases

Guidelines for using QoI fungicides on Cucurbit Vegetables

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Apply a maximum of 3 QoI fungicide sprays per crop
3. Use a maximum of 1 QoI fungicide spray out of every three fungicide applications.
4. Do not use consecutive applications of QoI fungicides.
5. Apply QoI fungicides in alternation with fungicides from a different cross-resistance group with satisfactory efficacy against the targeted pathogen(s).
6. Continue QoI fungicide alternation between successive crops.

2.2.2.7 Guidelines for using QoI fungicides on greenhouse grown non-cucurbit vegetables

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.
2. Use a maximum of 1 QoI fungicide spray out of every 3 fungicide applications.
3. Do not use consecutive applications of QoI fungicides.
4. Apply QoI fungicides in alternation with fungicides from a different cross-resistance group with satisfactory efficacy against the targeted pathogen(s).
5. Continue QoI fungicide alternation between successive crops.

2.2.2.8 Guidelines for using QoI fungicides on other multiple spray crops (non-cucurbit field vegetables and ornamentals)

1. Apply QoI fungicides according to manufacturers recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build up of resistant pathogen populations.
2. Observe spray limitations in the spray guideline table shown below for programmes utilising 12 or fewer fungicide sprays per crop.

Spray guideline table:

Total number of spray applications per crop	1	2	3	4	5	6	7	8	9	10	11	12	>12
Maximum recommended Solo QoI fungicide sprays	1	1**	2**	2	2	2	2	3	3	3	3	4	*
Max. recommended QoI fungicide sprays in mixture	1	2	2	2	2	3	3	4	4	5	5	6	*

* When more than 12 fungicide applications are made, observe the following guidelines:

- When using a QoI fungicide as a solo product, the number of applications should be no more than 1/3 (33%) of the total number of fungicide applications per season.
- For QoI mixes in programs in which tank mixes or pre mixes of QoI with mixing partners of a different mode of action are utilized, the number of QoI containing applications should be no more than ½ (50%) of the total number of fungicide application per season.
- In programs in which applications of QoI are made with both solo products and mixtures, the number of QoI containing applications should be no more than ½ (50%) of the total number of fungicide applied per season.

** Mixtures are preferred.

2.2.2.9 Banana

Guidelines for using QoI fungicides on banana

Please refer to the recommendations of the Banana FRAC working group: [hyperlink to Banana WG](#)

2.3. Communication plans

The above WebPages will serve as the main communication vehicle for the group.

Next meeting (to be organised by Du Pont):

- cereal crops: October 11th, 2005, preferably in connection with SBI FRAC meeting
- non-cereal crops: November 29th, 2005

Venue: Du Pont, Bad Homburg