



## MEMBERSHIP

The working group is comprised of the following members:

Andy Leadbeater (chair)	Syngenta
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Andreas Mehl	Bayer CropScience
Damien Viollet	Bayer CropScience
Georg Raupach	Bayer CropScience
Robert Bird	DuPont
Jean-Luc Genet	DuPont
Gerd Stammler	BASF
Martin Semar	BASF (arable crops)
Randall Gold	BASF (speciality crops)

## 1. 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, dimoxystrobin, enestroburin, famoxadone, fenamidone, fluoxastrobin, kresoxim-methyl, metominostrobin, orysastrobin, picoxystrobin, pyraclostrobin, pyribencarb, trifloxystrobin**

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

Companies participating in the meetings:

**BASF, Bayer CropScience, DuPont, Syngenta**

**QoI working group of FRAC  
Minutes of the meeting  
All crops: December 3<sup>rd</sup>, 2009  
Organised by Bayer CropScience in Frankfurt, Germany**

## 2. Minutes of discussions

### 2.1. Review of sensitivity monitoring

#### 2.1.1. Cereal diseases

Field experience in 2009 has confirmed that, when used according to FRAC guidelines, the performance of QoI containing products within spray programmes was good. QoIs continue to contribute to overall disease management in cereals.

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

Bayer CropScience

Disease pressure in 2009 was low to moderate across Europe.

No further monitoring was carried out in Northern and Western parts of Europe due to already established high levels of resistance as reported previously.

Overall, where monitoring was carried out, the situation in 2009 was similar to 2008.

High resistance frequencies were found in Southern France.

Low to medium resistance frequencies were found in Hungary, Austria, Czech Republic and Poland.

No resistance was found in Italy.

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

Bayer CropScience

Disease pressure in 2009 ranged from low to moderate across Europe.

An improved situation was confirmed compared to 2007, with lower levels of resistance in some countries.

High resistance levels were found in Northern and Central France, and the UK.

Medium to high levels were found in Ireland.

Low to medium frequencies were found in Germany, Denmark, Sweden and Poland.

No resistance was detected in Czech Republic, Austria, Hungary, Italy and Southern France.

#### **Septoria leaf spot (*Septoria tritici* = *Mycosphaerella graminicola*), wheat**

BASF, Bayer CropScience, Syngenta, Du Pont

Disease pressure in 2009 in Europe was low to moderate.

Extensive monitoring programmes were carried out throughout the wheat growing areas of Europe in 2009.

The status at the end of the season 2009 is as follows:

UK, Ireland, Belgium, Germany, The Netherlands: widespread resistance all over these countries at high levels.

France: heterogeneous populations with a decreasing gradient from North to South, i.e. high resistance levels in the North and centre (an increase from 2008), low to medium in the South.

Austria, limited sampling showed medium resistance levels. No monitoring was done in Switzerland: in 2009.

Czech Republic: 2009 data show a generally stable situation ranging from low to medium resistance levels.

Poland: 2009 data show a heterogeneous picture ranging from low to highly resistant populations with a tendency for an increase in resistance.

Denmark, Sweden, Latvia and Lithuania: 2009 data show medium resistance levels

Spain (South), Ukraine, Belarus, Finland: limited sampling in 2009 showed no to low levels of resistance

Russia: limited monitoring was carried out in 2009. In Krasnodar no resistance was found. In Kaliningrad medium resistance levels were found

### **Brown rust (*Puccinia recondita* = *Puccinia triticina*), wheat**

BASF, Bayer CropScience.

Disease pressure was moderate in most of the countries of Europe in 2009.

Performance of QoI fungicides against brown rust was good. No resistant isolates were detected in widespread monitoring studies in Europe in 2009, confirming the fully sensitive picture.

### **Net blotch (*Pyrenophora teres*), barley**

BASF, Bayer CropScience, Syngenta, Du Pont

Disease pressure was moderate in Europe during 2009. Performance of QoI containing spray programmes against Net Blotch was good.

Extensive monitoring was carried out in 2009. The F129L mutation (not the G143A mutation) was found. For the first time the G137R mutation was found in isolates from Ireland. As already observed with other pathogens, resistance factors are significantly lower in comparison with the G143A mutation and field performance of products used according to FRAC and Manufacturers' recommendations remains good. (For differences between QoI mutations see also the respective FRAC document).

Frequency of the F129L mutation in 2009 was comparable to 2007 and 2008 in barley growing countries in Europe.

The F129L mutation was found most frequently in populations in Central France and the UK, less frequently in Northern France, Belgium, Ireland and Denmark.

A few F129L containing - samples were detected in Germany, Southern France, Finland, Sweden. No mutation was found in Czech Republic, Italy, Latvia and Poland.

### **Leaf scald (*Rhynchosporium secalis*), barley**

BASF, Bayer CropScience, Syngenta, du Pont

Disease pressure was moderate in Europe during 2009.

Performance of QoI fungicides against Leaf Scald was good.

Extensive monitoring was carried out in 2009 which showed no G143A mutation in all countries (UK, Ireland, Germany, Netherlands, France, Czech Republic, Poland Denmark, Sweden, Spain).

The G143A mutation was not detected in samples from Northern France, where one sample containing this mutation was found in 2008.

A few studies are still in progress.

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

BASF, Du Pont

Disease pressure was low in Europe. Performance of QoI containing spray programmes against tan spot was good in 2009.

Resistance of Tan Spot to QoI fungicides has not spread rapidly (as compared with *M. graminicola*).

Samples containing the G143A mutation were found in Germany, Netherlands, France, Denmark, Latvia, Lithuania, Sweden, Poland, Czech Republic. However, levels were highly variable.

The frequency of resistance (G143A) has locally increased to medium levels in Southern Germany and Poland.

Samples containing the F129L mutation at lower frequency than the G143A mutation were found in Germany, France, Denmark. In Sweden the F129L mutation was found at medium to high levels, more frequent than the G143A (none to medium).

No mutations were found in samples from Finland and Russia (Krasnodar).

Characterisation of F129L isolates has shown a clear dose response to QoI fungicides.



Mutations associated  
with QoI resistance

All three point mutations known for QoIs, (G143A, F129L, G137R), have been detected, and can occur in the same population. The G137R mutation, first detected in 2006, which confers weak resistance (lower than F129L) was not detected in 2009. This is considered to be of low practical relevance.

### ***Microdochium nivale and majus*, wheat**

BASF, Bayer CropScience, Du Pont, Syngenta

Disease pressure was low to moderate in 2009..

Monitoring was carried out in 2009 on both species of *Microdochium* (*M. majus* and *M. nivale*). *M. majus* was the dominating species.

Extensive monitoring in Europe during 2009 confirmed resistance in both species due to the G143A mutation in several countries.

High levels were found in France and Germany.

Low to medium levels were found in Austria, Poland, Latvia, Estonia.

No resistance was found in Lithuania.

### ***Fusarium spp.*, wheat**

BASF

Monitoring was carried out in 2009 on *Fusarium culmorum* and *Fusarium graminearum* in France and Germany. A fully sensitive situation was found for both species.

### **2.1.2. Vine diseases**

#### **Downy mildew (*Plasmopara viticola*)**

BASF, Bayer CropScience, Syngenta

In 2009, disease pressure was moderate to high in the main grape growing areas of Europe. Disease management was challenging in many situations due to high disease pressure.

The levels of resistance found in monitoring programmes is summarised below:

High levels: France, Germany, Switzerland, Italy (Trentino, Alto Adige)

Moderate levels: Austria, Italy (other regions)

Low levels: Spain, Portugal

#### **Powdery mildew (*Uncinula necator* / *Erysiphe necator*)**

Bayer CropScience, Syngenta, BASF

Disease pressure in 2009 was variable across Europe, with high levels reported in France, Low disease pressure was reported in Austria and Hungary.

In 2009, intensive monitoring was carried out in Europe and no resistance was detected in Portugal, most of France, most of Italy, and most of Germany.

In 2009 resistance was again found in commercial locations in Eastern Austria, the Armagnac region of France, the Rioja region of Spain, the Alto Adige region of Italy, and Hungary,

First cases of resistance were found in the Lombardia region of Italy, the Mosel area of Germany and in the Constanta area of Romania

FRAC guidelines have been widely communicated across Europe and where these have been followed, field performance of QoI containing spray programmes was good. Adherence to FRAC guidelines must be stressed, especially in areas where resistance has been confirmed.

### **2.1.3 Pome fruit diseases**

#### **Apple scab (*Venturia inaequalis*)**

BASF, Bayer CropScience

Disease pressure was low to high across Europe.

FRAC guidelines have been widely followed, and field performance of QoI containing spray programmes was good across Europe.

Through intensive monitoring carried out in Europe it is known that in regions where resistance is present, the levels of resistance found are very heterogeneous, with values ranging from zero to high, even between neighbouring orchards.

Intensive monitoring was carried out in 2009, the frequencies of resistance are reported below:

High levels: Poland, Greece

Moderate to high levels: Southern France, Northern Italy and Eastern Germany

Low to moderate levels: Western Germany, Austria

Low levels: Spain, North-West France

No resistance was detected in UK, Portugal, the Lake Constance area of Germany.

Monitoring is still ongoing and remaining results, e.g. for Belgium, will be available beginning of 2010.

#### **Apple Powdery Mildew (*Podosphaera leucotricha*)**

BASF

Monitoring was carried out during 2009 in UK, Netherlands, Belgium, Southern France and Spain. No resistance was found in any sample.

#### **Apple storage rot (*Gloeosporium album*, *G. fructigenum*)**

BASF

Monitoring was carried out during 2008-9 in Northern Germany, the Lake Constance area of Germany, and in Austria, . No resistance was found in any sample.

### **2.1.4. Potato/tomato diseases**

#### **Late blight (*Phytophthora infestans*)**

Bayer CropScience, Du Pont

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

#### **Early blight (*Alternaria spp.*)**

No monitoring was carried out in 2009

### **2.1.5. Soybean diseases**

#### **Asian Rust (*Phakopsora pachyrhizi*)**

Bayer CropScience, Syngenta

Intensive monitoring was carried out across Brazil during 2009. No resistant isolates have been detected.

### **2.1.6. Other crops**

#### **Vegetables**

#### **Cucumber powdery mildew (*Sphaerotheca fuliginea*)**

BASF

Limited monitoring in Netherlands, Southern France and Southern Spain showed moderate to high frequencies of the G143A mutation.

### **Oilseed Rape (Canola)**

#### **Stem Rot (*Sclerotinia sclerotiorum*)**

BASF

Results from 2008 monitoring are not yet available

### **Cotton**

#### **Leaf spot (*Ramularia areola*)**

Syngenta, FRAC – Brazil

No information is available from the 2009 season

### **Rice**

#### **Blast (*Pyricularia oryzae*)**

BASF

Extensive monitoring in Japan during 2008 and 2009 shows a fully sensitive picture. The G143A and F129L mutations were not detected.

Further known cases of QoI resistance:



## **2.2. Review of global guidelines**

### **2.2.1 Strategies and Guidelines for the 2010 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, dimoxystrobin, enestroburin, famoxadone, fenamidone, fluoxastrobin, kresoxim-methyl, metominostrobin, oryastrobin, picoxystrobin, pyraclostrobin, pyribencarb, trifloxystrobin) 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 manufacturers' 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 solo 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, 2010 season**

Where the guidelines for the season 2009 were followed, field performance of QoI containing spray programmes was good. It continues to be essential to use non-cross resistant 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 2010 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* / *Erysiphe 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 (co-formulations or tank mixes) with effective mixture partners from different cross-resistance groups.
3. Apply QoI fungicides preventively.
4. QoI fungicides used solo should be used in strict alternation with fungicides from a different cross-resistance group.
5. Apply QoI fungicides used in mixture in a maximum of two consecutive applications in alternation with fungicides from a different cross-resistance group. In areas where resistance has been confirmed, apply QoI fungicides in strict alternation.

##### 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 Qol fungicide containing sprays per vine crop, only in mixture with effective partners from different cross-resistance groups.
4. Apply Qol 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 Qol fungicides on pomefruit**

##### Scab (*Venturia inaequalis*, *Venturia pirina*)

1. Apply Qol 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. Qol fungicides must be applied only in mixture with partners contributing to the effective control of the target pathogens.
3. Apply Qol fungicides preventatively. Under high disease pressure the spray interval should not exceed 7-10 days.
4. Apply a maximum of 3 Qol containing sprays per crop. A maximum of 4 Qol fungicide applications may be used where 12 or more applications are made per crop.
5. A maximum of 2 consecutive Qol fungicide sprays is preferred. Where field performance was adversely affected apply Qol 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 Qol fungicides on potatoes and tomatoes**

##### Late blight (*Phytophthora infestans*)

1. Apply Qol 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 Qol 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 Qol 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 Qol fungicide applications whichever is the lower. Do not use more than 3 consecutive Qol fungicide containing sprays.

##### Early blight (*Alternaria solani*, *Alternaria alternata*)

1. Where Qol 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 Qol 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 (co-formulations or tank mixes) 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: The conclusions and guidelines of the Feb. 2008 meeting of the FRAC Banana Working Group are available on the [FRAC Website](#). The next meeting of the group is planned for March 10-11<sup>th</sup>, 2010.

### **2.3. Communication plans**

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

#### **Next meetings:**

All crops: December 2<sup>nd</sup> 2010.

Venue: TBA (probably Frankfurt)