MEMBERSHIP

The working group is comprised of the following members:

Andy Leadbeater (chair)	Syngenta
Helge Sierotzki	Syngenta
Luc Henry	Syngenta
Andreas Mehl	Bayer CropScience
Frank Goehlich	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, coumoxystrobin, dimoxystrobin, enoxastrobin, famoxadone, fenamidone, fenaminostrobin, fluoxastrobin, flufenoxystrobin, kresoxim-methyl, metominostrobin, orysastrobin, pyraoxystrobin picoxystrobin, pyraclostrobin, pyrametastrobin, pyribencarb, triclopyricarb 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 8th, 2011
Organised by BASF in Frankfurt, Germany

2. Minutes of discussions

2.1. Review of sensitivity monitoring

2.1.1. Cereal diseases

Field experience in 2011 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

No monitoring was carried out during 2011

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

No monitoring was carried out during 2011

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

BASF, Du Pont, Bayer CropScience, Syngenta

Disease pressure in 2011 in Europe was low to moderate with a late onset of disease.

Extensive monitoring programmes were carried out throughout the wheat growing areas of Europe in 2011.

The status at the end of the season 2011 is as follows:

France, Germany, The Netherlands, Lithuania, Sweden, Great Britain, Denmark, Ireland: widespread resistance all over these countries at high levels.

Poland: heterogeneous populations from no to high levels of resistance.

Czech Republic: 2011 data show a generally stable situation with the majority of samples ranging from low to medium resistance levels. A few samples with high resistance levels were detected in parts of the country. Italy, Belarus, Latvia: heterogeneous populations from no to moderate levels of resistance.

Ukraine, Spain, Romania, Bulgaria, Russia Slovakia, Croatia: sampling in 2011 showed no to low levels of resistance.

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

BASF

Disease pressure was moderate in most of the countries of Europe in 2011.

Performance of QoI fungicides against brown rust was good. No resistant isolates were detected in widespread monitoring studies in Europe in 2011, confirming the fully sensitive picture.

These findings are consistent with the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur.

Impact of Intron

Brown Rust / Dwarf rust (*Puccinia hordei*) barley

Bayer Crop Science

During first QoI sensitivity studies with *Puccinia hordei* in 2010 1 isolate with slightly higher EC50 values to QoIs (factor 11) was detected in France. However the mutations normally associated with QoI resistance were not found.

In 2011 continued monitoring studies also showed some isolates with slightly higher EC50 values in UK and northern France (mean resistance factor 15). The practical relevance of these findings is not currently known. The mechanism is not known, no relevant mutations have been found.

Field performance in 2011 of QoI containing spray programmes was good.

Net blotch (*Pyrenophora teres*), barley

BASF, Bayer CropScience, Syngenta, Du Pont

Disease pressure was low to moderate in Europe during 2011. Performance of QoI containing spray programmes against Net Blotch was good.

Extensive monitoring was carried out in 2011. The F129L and (less frequently) the G137R mutations (not the G143A mutation) were found. 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).

These findings are consistent with the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur.

Impact of Intron

The situation at the end of the 2011 season was:

UK, France – moderate to high frequency of the F129L mutation

Germany, Denmark, Belgium – low to moderate levels

Sweden, Poland, Czech Republic - low levels.

Norway, Finland, Lithuania, Latvia, Ukraine, Belarus, Austria, Ireland – no detection of mutations.

Leaf scald (*Rhynchosporium secalis*), barley

BASF, Bayer CropScience, Syngenta, Du Pont

Disease pressure was low in Europe during 2011.

Performance of QoI fungicides against Leaf Scald was good.

Extensive monitoring was carried out in 2011 which showed no G143A mutation in all countries (UK, Ireland, Germany, France, Czech Republic, Poland, Denmark, Sweden, Latvia, Norway, Finland).

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 2011.

Resistance of Tan Spot to QoI fungicides has spread further during 2011

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

All three point mutations known for QoIs, (G143A, F129L, G137R), have been detected, and can occur in the same population. The G137R mutation, which confers weak resistance (lower than F129L) is seldom detected and is considered to be of low practical relevance.

Mutations associated with QoI resistance

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

Du Pont

Monitoring was carried out in 2011 on both species of *Microdochium* (*M. majus* and *M. nivale*).

Monitoring in Northern / Easterm Europe during 2011 confirmed resistance in both species due to the G143A mutation in several countries.

High levels were found in Poland, Sweden and Denmark.

Resistance was reported in the Hokkaido prefecture in Japan during 2011.

***Fusarium spp.*, wheat**

No monitoring was carried out during 2011

***Ramularia collo-cygni*, barley**

Bayer Crop Science, Syngenta

Results from 2011 monitoring are not yet available.

Monitoring was carried out in 2010 in UK, Ireland Germany, France, Denmark.
The G143A mutation was detected at high levels.

2.1.2. Vine diseases

Downy mildew (*Plasmopara viticola*)

BASF, du Pont

In 2011, disease pressure was moderate in the main grape growing areas of Europe.

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

High levels: Germany (Mosel), Czech Republic, Slovakia

Moderate levels: France, Hungary, Austria, Spain (Galicia), Portugal, Italy, Switzerland
Low levels: Spain

No resistance was found in Romania, Greece

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

Bayer CropScience, Syngenta, BASF

Disease pressure in 2011 was low to moderate across Europe.

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

In 2011, intensive monitoring studies show there was a further spread of resistance in Europe compared to 2010, with an increase in frequency in some areas.

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

High levels: Austria, Czech Republic, Romania. Hungary, Slovakia, Italy (Tuscany, S. Tirol, Lazio) France (Armagnac), Germany (Württemberg).

Low levels: Germany (Rheinhessen, Baden), Spain (Rioja), France (South-East, Champagne), Italy (Emilia Romagna,Trentino, Veneto).

No resistance was detected in Portugal,

Heterogeneous levels of sensitivity (low to high levels) were identified in other regions of France (Languedoc, Burgundy, Bordeaux, Cognac) Germany (Mosel, Palatinate, Franken), Spain (Catalunia, Navarra) and Italy.

Resistance was detected for the first time in a trial site in Australia

2.1.3 Pome fruit diseases

Apple scab (*Venturia inaequalis*)

Bayer CropScience

Disease pressure in 2011 was low across Europe.

Field performance of QoI containing spray programmes was generally 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 2011 - frequencies of resistance are reported below:

High: Western Germany, Poland, Netherlands.

Moderate to High: Southern France, Northern Germany and Belgium.

Low to moderate: Southern Germany..

No to low: North-West France and UK.

Resistance was confirmed in New Zealand and Southern Brazil.

Monitoring data from 2010 in Portugal showed that resistance was detected, most samples were sensitive. No monitoring was performed in Portugal in 2011.

Apple Powdery Mildew (*Podosphaera leucotricha*)

No monitoring data are available from 2011

Monitoring was carried out during 2010 in UK, Germany, Austria, Netherlands, France, Italy and Spain. No resistance was found in any sample.

2.1.4. Potato/tomato diseases

Late blight (*Phytophthora infestans*)

Du Pont

No resistance was detected in all isolates collected in 2011 from potato crops France, Germany, UK, Denmark, Poland, Portugal, Sweden. Performance remains good.

Early blight (*Alternaria spp.*)

BASF, Syngenta

Monitoring was carried out in potatoes (*Alternaria solani* and *Alternaria alternata*) in Europe in 2011.

Alternaria solani

All samples tested were sensitive (France, Germany, Netherlands, Switzerland, Poland, Serbia, Czech Republic).

Alternaria alternata

Isolates containing the G143A mutation were found in samples from: Germany, Netherlands, Switzerland, Poland, Czech Republic

No G143A mutation was found in samples from France and Serbia

The role of *A.alternata* in the disease complex has to be clarified.

2.1.5. Soybean diseases

Asian Rust (*Phakopsora pachyrhizi*)

Bayer CropScience, Syngenta

Intensive monitoring was carried out across Brazil during 2010/2011. No resistant isolates have been detected.

These findings are consistent with the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur.

Impact of Intron

Frogeye spot (*Cercospora sojina*)

Syngenta

Resistance due to the G143A mutation was confirmed in a small number of samples from USA (Tennessee)

2.1.6. Other crops

Vegetables

Cucumber powdery mildew (*Sphaerotheca fuliginea*)

No monitoring was carried out in 2011.

Asparagus. *Stemphyllium spp*

BASF

Monitoring was carried out in Germany in 2010 and 2011, high levels of G143A were detected in most samples.

Oilseed Rape (Canola)

Stem Rot *(Sclerotinia sclerotiorum)*

Monitoring results from UK, Germany, France and Poland in 2011 show a fully sensitive situation.

BASF, Syngenta

Results from 2009 and 2010 show a fully sensitive situation in Germany, UK, France, Czech Republic, Denmark, Poland, Sweden and Slovakia.

Corn

Northern Leaf Blight (*Setosphaeria turcica*)

BASF

Monitoring results from Germany and Belgium in 2010 show a fully sensitive situation. No G143A or F129L mutations were found. No monitoring was carried out in 2011.

Cytochrome b gene analysis showed the presence of an intron directly after codon 143 in this species making the G143A mutation lethal and therefore unlikely to occur.

Impact of Intron

Cotton (*Ramularia areola*)

No monitoring was carried out in 2011

Monitoring results from 2008 and 2009 show a high number of isolates with a reduced level of sensitivity compared with the wild type.

Confirmation of target site mutations by molecular tests has not yet been done

Rice

Blast (Pyricularia oryzae)

BASF

Good field performance of QoIs in Japan. No resistant isolates were found in 2011.

Sheath blight *(Rhizoctonia solani AG1.1A)*

Samples in 2011 from a small number of fields in Louisiana, USA were found to contain less sensitive isolates. The F129L mutation has been found in these isolates.

Further known cases of QoI resistance:

Species with QoI-resistance

2.2. Review of global guidelines

2.2.1 Strategies and Guidelines for the 2012 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, coumoxystrobin, dimoxystrobin, enoxastrobin, famoxadone, fenamidone, fenaminostrobin, fluoxastrobin, flufenoxystrobin, kresoxim-methyl, metominostrobin, orysastrobin, pyraoxystrobin picoxystrobin, pyraclostrobin, pyrametastrobin, pyribencarb, triclopyricarb trifloxystrobin) are in the same cross-resistance group.

- Fungicide programmes 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, 2011 season

Where the guidelines for the season 2010 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 2011 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

Apply a maximum of 5 QoI fungicide containing sprays against any disease per vine crop, and a maximum of 50% of the total number of applications.

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 targeted against powdery mildew per vine crop, preferably 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 QoI fungicide containing sprays targeted against downy mildew 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

Scab (*Venturia inaequalis, Venturia pirina*)

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, Alternaria alternata*)

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 (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 March 2010 meeting of the FRAC Banana Working Group are available on the FRAC Website (http://frac.info/frac/work/work_bana.htm). The next meeting of the group is planned for 2012.

2.3. Communication plans

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

Next meetings:

All crops: December 6th 2012.

Venue: Frankfurt