

MEMBERSHIP

The work group is comprised of the following members:

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INTRODUCTION

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

The Qo fungicides are: azoxystrobin, famoxadone, fenamidone, kresoxim-methyl, picoxystrobin, pyraclostrobin, trifloxystrobin, fluoxastrobin, metominostrobin, oryzastrobin and dimoxystrobin.

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 meetings

Cereal part: on October 10th, 2003, Edenkoben / Germany
Non-cereal part: on November 25th 2003, Bad Dürkheim, Germany
Both organised by BASF

- 1. Agenda**
 - 1.1. Review of 2003 sensitivity monitoring**
 - Cereals**
 - Vines**
 - Pome fruit**
 - Cucurbits**
 - Potato/tomato**
 - 1.2. Review of 2004 guidelines**
 - 1.3. 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

No further monitoring has been done in 2003 in North Western Europe. Already in 2002 high levels of resistance were found in the main wheat growing countries in Europe.

Bayer CropScience

No resistance was detected in Austria, Hungary and the Czech Republic.

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

BASF, Bayer CropScience, Syngenta

In general the frequency of resistant isolates increased in 2003 compared to 2002, however the spread of resistant barley powdery mildew isolates is slower than that observed previously for wheat powdery mildew. Some resistant strains were detected in Denmark and Sweden. Moderate frequencies of resistance were detected in UK and Ireland. The picture in Germany is still heterogeneous with higher values found in the northern regions. Higher frequencies of resistance were found in Northern France and in Belgium. No resistance was detected in Austria and Italy. Field performance was good when QoI products were applied in mixtures as recommended by the QoI FRAC guidelines.

Septoria leaf spot (*Septoria tritici*), wheat

BASF, Bayer CropScience, Syngenta

Extensive monitoring programmes were carried out throughout the wheat growing areas of Europe in 2003. Due to the first detection of resistant strains late in the 2002 season monitoring programmes were carried out to determine the geographical distribution of resistance in Europe. Therefore samples have been taken in winter, early spring and during summer.

Disease pressure in 2003 was low to moderate due to predominantly dry weather conditions. High disease levels were observed in Ireland where rainfall was higher.

In contrast to what was expected at the beginning of 2003 the spread of resistance is quite fast. In the monitoring programmes resistance was detected in all major wheat growing countries in Western Europe (as detailed hereafter). Generally in-season monitoring data show increased resistance levels compared to pre-season samplings, as well as further geographical distribution. Different analysis methods (detached leaf assay, microtiter plate assays, PCR, q-PCR, Pyrosequencing) with more than 10.000 data points in 2003 resulted in comparable data across companies. Status at the end of the season 2003 is as follows:

Ireland: widespread all over the country at high levels

UK: widespread at moderate to high levels in Southern regions, but low to moderate in the rest of the UK and Scotland

France: heterogeneous populations with low to high levels in the North of France (Pas-de-Calais and Picardie), low or no resistance elsewhere

Germany: heterogeneous picture in the North (Schleswig-Holstein, Mecklenburg-Vorpommern, Niedersachsen, Nordrhein-Westfalen) ranging from low to high levels, low or no resistance elsewhere

Belgium, The Netherlands: heterogeneous picture, areas without resistance and locations with high levels

Denmark: low to moderate levels

Sweden, Poland, Czech Republic: low or no resistance

Field performance of spray programmes with QoI containing products was good in 2003 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 2003, confirming the fully sensitive picture already established.

Net blotch (*Pyrenophora teres*), barley

BASF, Syngenta, Bayer CropScience

Performance of QoI fungicides against net blotch was good. Monitoring data from 2002 showed a fully sensitive picture. 2003 monitoring data were not available at the time of the meeting.

Leaf scald (*Rhynchosporium secalis*), barley

Syngenta

Performance of QoI fungicides against leaf scald was good. Preliminary monitoring data from 2003 showed a fully sensitive picture for the UK and Ireland. More data will be available before the end of 2003.

2.1.2. Vine diseases

Downy mildew (*Plasmopara viticola*)

BASF, Bayer CropScience, DuPont, Syngenta

In 2003, disease pressure was low in the main grape growing areas of Europe. Infestation only occurred towards the end of the season.

All companies carried out major monitoring programmes in 2003 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.

No resistant strains were detected in Austria. For the first time resistant strains could be found in Portugal (Peninsula de Setubal) at low levels. In general, compared to 2002 a slight increase in the frequency of detection of the resistant strains was observed in France whereas the situation in the other countries was unchanged. Heterogeneous results have been reported in Italy indicating both increase and decrease in the frequency of resistance which might be explained by differences in the methods employed and the late occurrence of the disease in 2003.

The occurrence of the second target site mutation F129L was confirmed for France and identified in Spain (1 sample) at very low frequencies. Resistance factors of approx. 10 were recorded and emphasize the low practical relevance of this mutation. As a consequence no further analyses on this mutation will be done in 2004.

Where FRAC guidelines were followed field performance of QoI containing spray programmes was good across Europe and frequently provided better disease control compared to non-QoI containing programmes.

Powdery mildew (*Uncinula necator*)

Disease pressure was low across Europe.

No 2003 data available yet

One case of reduced field performance to QoI in USA (NY) is under investigation. No complaints are recorded elsewhere.

2.1.3 Pome fruit diseases

Apple scab (*Venturia inaequalis*)

BASF, Bayer CropScience

Disease pressure was low across Europe. Infestation only occurred towards the end of the season.

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

Target site mutants (G143A) were found for the first time in France, Belgium, Netherlands, Czech Republic and Hungary. Levels of resistance were generally low except for two sites in France (Montauban, Nîmes).

Performance of QoI fungicide programmes under both trial and commercial conditions was generally good.

Despite the detection of resistance in European apple growing regions since several years the spread of resistant populations remains limited. A clear lack of correlation between detection of target site mutants and disease control is evident.

2.1.4. Cucurbit diseases

Powdery mildew (*Sphaerotheca fuliginea*)

No data generated in 2003

High frequencies of resistant isolates have previously been detected in Japan, Taiwan, Spain, Israel and Southern France, and in these countries field performance was affected. Resistance has also been previously detected at several locations in the UK, Netherlands, North West France, Italy and Korea.

Downy mildew (*Pseudoperonospora cubensis*)

No data generated in 2003

Resistance have previously been detected in Japan and Taiwan 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, Scandinavia, Portugal and Poland. Performance remains good.

Early blight (*Alternaria solani*)

Syngenta

Cases of reduced sensitivity, found in 2002 in the USA, were followed up regarding frequency and practical relevance of the F129L mutation.

Isolates carrying the F129L mutation were detected in 2003 in Nebraska, North Dakota and Wisconsin. Resistance factors were confirmed to be low.

Field performance was good.

2.2. Review of guidelines

2.2.1 Strategies and Guidelines for the 2004 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 and oryzastrobin) 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.
- 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 for 2004

2.2.2.1 Cereal diseases

The field performance of QoI containing spray programmes was good in 2003, but the build up and further spread of resistance of *Septoria tritici* could not be prevented. Therefore it is essential to strengthen the role of non-crossresistant mixture partners (e.g. SBIs, multisites) to ensure robust disease management. This will also help to delay the evolution of Septoria resistance especially in regions with no resistance or where resistance is at low levels.

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 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 new emerging disease of major importance in Latin America. There is limited experience at this point in time in terms of rust epidemiology, disease management (including maximum number of QoI applications) and resistance risk.

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.

Spray guideline table:

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

* Where more than 12 fungicide applications are made, do not use more than one third of all fungicide applications with QoI fungicides solo or 50% where used in mixture.

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.

2.2.2.9 Banana

Guidelines for using QoI fungicides on banana

The next meeting of the FRAC banana Working Group is scheduled for 11/ 12 February 2004. Guidelines will be updated accordingly.

Black Sigatoka (*Mycosphaerella fijiensis*)

The following guidelines were updated following a FRAC meeting held in San Jose, Costa Rica on August 8th, 2000. This meeting was called specifically to discuss what changes to the guidelines should be recommended by FRAC in response to the detection of strains of *Mycosphaerella fijiensis* resistant to the strobilurin fungicides in multiple locations in Costa Rica. Revised guidelines for strobilurins (Qo inhibitors) are listed under items 16 to 23. Where guidelines have been modified from those agreed at the FRAC meeting in Miami (February, 2000) they are shown in bold type. Guidelines for other fungicides remain unaltered.

1. Field experience in bananas in Central America has shown that *M. fijiensis* can develop resistance to the DMI fungicides. The DMIs are and will continue to be very key tools for the efficient control of Black Sigatoka in bananas. An effective anti-resistance strategy must be followed when using these materials, in order to protect their fungicidal performance over the long term.
2. In general terms, the use of fungicides with a different mode of action applied in tank mixtures or in alternated sprays are both suitable approaches to diminish the risk of resistance development. These use strategies are particularly valuable in the case of site specific systemic fungicides and in situations when there is a need to cope with a shift towards decreased sensitivity. The anti-resistance strategies only allow a limited number of sprays with the systemic fungicides (see items 9-10). Therefore, the use of these materials in alternation with fungicides belonging to other classes seems to be the best approach in order to allow the necessary total number of sprays which are required with the systemic fungicides, for efficient Black Sigatoka control over the whole high pressure period.
3. The use of the full recommended label rate of DMIs is strongly urged (straight DMI use).
4. The DMIs must be used at least $\frac{3}{4}$ of their full recommended label rates when they are applied in tank mix with other systemic fungicides. When tridemorph is the partner compound, it must be added at least at $\frac{2}{3}$ its commercially recommended label rate. In the case of tank mixtures with benzimidazoles, these fungicides must be used at their full recommended label rates. Finally, when mancozeb is used as the partner material for site specific systemic fungicides, these DMIs must be applied at their full recommended label rates.
5. Single alternation of DMIs with other systemic fungicides is recommended. Repeated (sequential) applications of DMIs (either alone or in tank mixtures with other systemics) must be limited to no more than 2 consecutive sprays (i.e. block of 2 sprays). The same recommendation is also applicable to tridemorph.
6. All the fungicides belonging to the DMI's class are considered to be a single product group, amongst which there is in general some degree of cross-resistance. Therefore, alternation or mixtures of DMIs must not be recommended for the purpose of resistance management.
7. The benzimidazole fungicides must not be applied in consecutive sprays. The applications of benzimidazole fungicides should not exceed a total of 6 sprays in a period of 12 months. It is also recommended that this class of fungicides must be always used in mixtures with mancozeb.
8. In the case of straight applications of the DMIs, the number of sprays against Black Sigatoka must not exceed a total of 8 cycles during any 12 month period (a maximum of 6 total sprays in the case of Yellow Sigatoka).
9. The maximum number of DMI's sprays for controlling Black Sigatoka might be increased to a total of 10 applications in a 12 month period, if the DMIs are always applied in mixtures with other systemics (7 maximum sprays in the case of Yellow Sigatoka).
10. The number of tridemorph sprays with this fungicide used either alone, in mixture with the DMIs or other classes of fungicides must not exceed a total of 12 applications within a 12 month period.
11. Protective (preventative) fungicides are considered to be a very valuable and necessary tool for the banana Sigatoka control programs.

12. The systemic fungicides must only be applied in oil or oil-water emulsions.
13. A DMI-free period of at least 2 (and if possible 3-4) consecutive months, during the periods of lower disease pressure is recommended.
14. DMIs should be applied to achieve as early a curative control as possible.
15. Eradicative use of DMIs should be avoided.
16. A maximum of 4 cycles of strobilurin fungicides (QoI fungicides) should be used during a 12 month period.
17. Strobilurin applications (QoI fungicides) should be limited to a maximum of 3 exposure periods per calendar year.
18. Strobilurins (QoI fungicides) should only be applied in April, August and December in Costa Rica. In other countries, exposure periods should be defined locally, with 3 months between exposure periods as a working guideline.

In regions where high levels of strobilurin (QoI)resistance have been detected, strobilurin sprays should be discontinued until there is evidence of a significant increase in the frequency of sensitive strains.
19. Do not exceed recommended label spray intervals.
20. Do not apply strobilurins (QoI fungicides) in successive sprays
21. Apply full recommended label rates of the strobilurins (QoI fungicides) alone or in mixtures. Mixtures with fungicides with different modes of action are valuable for disease control and resistance management.
22. Strobilurins (QoI fungicides) should be applied to give as early a curative control as possible.
23. The eradivative use of strobilurins (QoI fungicides) should be avoided.

2.3. Communication plans

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

Details of sensitivity monitoring methodology for various diseases are currently being collected and will be made accessible on the web by the end of Q2 2004.

Next meeting (to be organised by Syngenta):

- cereal crops: 12th of October 2004
- non-cereal crops: 30th of November 2004