



Quinone ‘outside’ inhibitor (Qol) Working Group

Meeting on January 23rd, 2020, 8:00 am - 17:00 am

Protocol of the discussions and use recommendations of the Qol Working Group of the Fungicide Resistance Action Committee (FRAC)

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Qol working group of FRAC
Minutes of the meeting
All crops: January 23rd, 2020
held in Frankfurt, Germany

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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, mandestrobin, metominostrobin, oryastrobin, pyraoxystrobin, picoxystrobin, pyraclostrobin, pyrametostrobin, pyribencarb, triclopyricarb, trifloxystrobin

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

2. Minutes of discussions

2.1. Review of sensitivity monitoring

In the text below the categorisation of the findings ranging from “high” to “no resistance” are based on agreed frequency of resistant or adapted isolates in collections of samples from the respective countries or regions mentioned (no, no to low, low, low to medium, medium, medium to high, high, low to high, no to high resistance). Please refer to the wording in each category for more specific information.

2.1.1. Cereal diseases

Field experience in 2019 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

Companies: Bayer

Monitoring has been carried out in Czech Republic, Latvia, Lithuania and Poland.

Findings:

Medium to high frequencies of resistance were found in Latvia, Lithuania and Poland.

Low to medium in: Czech Republic

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

Companies: Bayer

Monitoring: Overall, where monitoring was carried out, there was a similar situation in 2018 as compared to 2017.

Limited monitoring in 2019

Findings:

No to Low in: Latvia and Lithuania.

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

Companies: BASF, Syngenta

Disease information: Disease pressure was moderate in Europe in 2019.

The status at the end of the season 2019 is as follows:

Findings:

In Belgium, France, Germany, Ireland, Netherlands, Sweden, and United Kingdom: widespread resistance over all these countries at high levels were detected.

Medium to high resistance level was detected in Poland.

In Austria, Switzerland, Czech Republic, Lithuania, Spain: populations were showing in average moderate levels of resistance with high variability.

Low to moderate in: Italy Slovakia, Romania and Ukraine.

No to low levels of resistance were found in Bulgaria, Greece, Russia and Turkey.

Additional information for other countries is given in the 2018 minutes.

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

Companies: Syngenta

In 2019, performance of QoI fungicides against brown rust was good.

Findings:

No resistant isolates were detected in widespread monitoring studies in Europe in 2019, confirming the fully sensitive picture (Belgium, France, Germany and United Kingdom).

Additional information: These findings are consistent with the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur (see FRAC QoI Intron Document).

Yellow rust (*Puccinia striiformis*), wheat

Companies: Bayer

Findings:

All isolates tested from Belgium, Germany, Denmark, Latvia, Sweden and United Kingdom were sensitive.

Net blotch (*Pyrenophora teres*), barley

Companies: BASF, Bayer, Syngenta

Disease information: Disease pressure was moderate within European countries in 2019. Field performance of QoI-containing fungicides against net blotch was good.

Monitoring: Data from 2019 was shared.

Additional information: Mainly the F129L mutation was 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 titled "Mutations associated with QoI resistance" available on the FRAC website under QoI fungicides →Quick references).

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

Findings

The situation in 2019 is as follows:

Medium to high in: DK

Medium levels were detected in: Belgium, Germany, France and United Kingdom.

No to medium in: Ireland

Low in: Netherlands, Sweden and Switzerland

No to low levels in: Austria, Bulgaria, Czech Republic, Italy, Latvia, Poland, Romania, Russia, Slovakia, Spain and Ukraine

No resistance of mutation was found in: Greece and Hungary.

In 2017 control of net blotch, esp. in areas in France, was difficult and potentially related to e.g. the high disease pressure, low varietal diversity, coupled to the reported breakdown of variety-resistance (variety ETINCEL) at significant cultivation areas and higher frequencies of mutated strains.

Leaf scald (*Rhynchosporium secalis* = *Rhynchosporium commune*), barley

Companies: BASF, Bayer,

Monitoring: Performance of QoI fungicides against Leaf scald was good.

Findings:

In 2019, samples were sensitive in: Belgium, Denmark, France, Germany, Ireland, Poland, Slovakia and United Kingdom.

Additional information: However, in some years since 2008 (e. g., 2012, 2013 France, 2014 UK, 2015 Spain, 2019 United Kingdom), occasionally isolates/samples have been found containing the G143A mutation. The frequency is always very low.

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

Companies: BASF, Syngenta

Findings:

Samples distributed over countries containing the G143A mutation were found at the frequencies indicated below, partly based on limited number:

High frequency in: Denmark and Latvia

Medium to high in: Hungary and Poland

Medium resistance frequencies were found in: Germany

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Low in: Austria

No in: Bulgaria and United Kingdom

Single resistant samples/isolates were found in: Finland, Latvia, Ukraine and Russia

Additional information: Although all three point mutations known for QoIs (G143A, F129L, G137R) have been detected in the past, and can occur in the same population, the G143A mutation is now dominant in this pathogen.

Ramularia leaf spot (*Ramularia collo-cygni*), barley

Syngenta

Findings 2018:

High frequency of G143A in: Denmark, France, Hungary, Ireland, Spain and United Kingdom

Moderate frequency of G143A in: Germany, Italy and Romania

Low frequency of G143A was found in: Austria and Switzerland

2.1.2. Vine diseases

Downy mildew (*Plasmopara viticola*)

No monitoring was carried out in 2019.

Companies: BASF, Syngenta, Corteva

Disease information: In 2018, disease pressure was high in the Southern regions of Europe and low elsewhere in Europe.

The levels of resistance found in monitoring programmes **in 2016 and 2017** are summarised below:

Findings:

High levels in: Croatia, Germany (Mosel, Rheinhessen), France (Centre, Champagne, Franche Comte and Poitou Charentes), Spain (Basque), and Switzerland (Vaud).

In vine growing regions of Brazil the G143A mutation has been detected at medium to high levels in 2017

Medium levels in: Bulgaria, Czech Republic, France (Aquitaine, Pay de la Loire), Germany (Baden Wuerttemberg, Franken), Hungary, Italy (Süd Tirol, Piemonte, Toscana, Emilia Romagna, Marche, Friuli, Veneto Abruzzo, Puglia), Portugal, Slovenia and Romania.

Low to medium levels in: Austria, France (Languedoc Roussillon, Lorraine, Midi Pyrenees), Greece, Portugal, Spain (Galicia), Switzerland (Zürich) and Slovakia.

Low levels in: Italy (Trentino).

No to low levels of resistance based on G143A mutation has been found in China in 2017.

Additional information: After numerous years of sensitivity monitoring carried out in Europe it has been observed the levels of resistance found are very heterogeneous, with values ranging from zero to high even between neighbouring vineyards.

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

Companies: BASF, Syngenta

Disease information: Disease pressure in 2019 was moderate across Europe.

The levels of resistance found in monitoring programmes in 2019 are summarised below:

Findings:

High levels were reported from: Austria, France (Champagne, Bourgogne, Bordeaux), Germany (Rheinhessen, Bavaria, Baden Württemberg), Greece, Northern Italy and Ukraine

Moderate in: France (Loire), Germany (Mosel), Italy (Emilia Romagna, Marche, Tuscany)

Low to moderate: France (Rhône (low) and Val de Loire (moderate))

No to high in: Turkey

Single resistant samples/isolates were found in: Spain

Additional information for other countries is given in the 2018 minutes.

2.1.3 Pome fruit diseases

Apple scab (*Venturia inaequalis*)

Companies: BASF, Bayer

Monitoring is ongoing

Disease information: Disease pressure in 2019 was moderate across Europe.

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

Findings in 2019:

High level was found in: Germany (mainly southern/south-West-Germany locations were sampled).

Limited number of samples from outside of Europe showed high frequencies in Japan, moderate in New Zealand and full sensitivity situation in Australia.

Monitoring carried out in 2017 indicating following resistance levels:

High in: Belgium, Germany, Hungary, Italy and Poland

Resistance based on the G143A mutation was detected in Japan, Aomori prefecture.

Medium in: France

Heterogeneous situation found in Spain from zero to high levels.

Samples from India (Kashmere) were all sensitive.

Additional information for other regions is given in the 2017 minutes.

Brown Rot in Stone Fruit (*Monilinia spp.*)

Companies: BASF

Findings:

In 2014/15:

No resistance: Monitoring data for 2014 and 2015 showed all populations to be fully sensitive (France, Greece, Hungary, Italy, Poland and Spain) (BASF, Bayer).

In 2016:

No resistance: Samples from France, Greece, Hungary, Italy and Poland were sensitive.

In 2018:

The analysis for *Monilinia* species present in monitoring samples from 2017 and 2018 showed a higher frequency of *M. fructicola* and *M. laxa* compared to *M. fructigena*.

No resistance in: France, Germany, Greece, Italy and Poland

In 2019:

The analysis of *Monilinia* species present in monitoring samples from 2019 showed a higher frequency of *M. fructicola* and *M. laxa* compared to *M. fructigena*.

No resistance: in France, Italy, Greece, Poland, Germany, Hungary, Spain

Additional information: These findings are most likely to be related to the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur (see FRAC document titled "Impact of Intron at G143A on Qo resistance development" located on the FRAC website under QoI fungicides (link)).

Most of the isolates were identified as *M. laxa* and *M. fructicola*. *M. fructigena* was seldom isolated.

***Stemphylium versicarium* on Pears, Onion and Asparagus**

Companies: Syngenta

Findings:

High frequency of QoI resistance was monitored in samples from Portugal (Pears)

Single resistant samples/isolates were found in: Croatia, Netherlands (onion), Spain and United States (spinach, 2018 data)

2.1.4. Storage diseases

***Neofabraea alba* and *N. perennans* (bull's eye rot), apples**

No monitoring was carried out in 2019

Companies: BASF

Findings of 2018:

All *N. alba* samples from Belgium, France, Hungary Italy and Poland were sensitive. All *N. perennans* samples from Germany were sensitive.

2.1.5. Potato/tomato diseases

Late blight (*Phytophthora infestans*)

No monitoring was carried out in 2019

Companies: BASF

Findings:

No resistance was detected in all isolates collected in 2018 from potato crops in Belgium, France and Netherlands.

Performance remains good.

Early blight (*Alternaria* spp.)

Alternaria solani

Companies: BASF, Bayer, Syngenta

Monitoring: Monitoring was carried out in potatoes (*Alternaria solani*) in Europe in 2019.

Findings:

-Potato

Resistance to QoI is associated to the presence of the F129L mutation and molecular information are provided below:

High frequency was detected in Austria, Denmark, Germany, Hungary, Netherlands, Norway and Sweden

Heterogeneous frequencies ranging from no to high in: Belgium, France, Poland and United Kingdom

Less sensitive isolates were found at low frequency in samples from Croatia and Czech Republic

No resistance was detected in: Greece and Ireland

Single strains/samples with F129L were found in: Latvia

Additional information: 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 titled "Mutations associated with QoI resistance" available on the FRAC website under QoI fungicides → (link)).

Black scurf (*Rhizoctonia solani* AG 3)

Companies: Syngenta

Potato:

Only sensitive samples were found in 2018 from Germany, Netherlands, Spain and United Kingdom

2.1.6. Soybean diseases

Asian Rust (*Phakopsora pachyrhizi*)

Companies: BASF, Bayer, Corteva, FMC, FRAC Brazil, Syngenta

Findings:

In 2013/14, isolates containing the F129L mutation were reported in a number of samples at low to medium range. However, sensitivity monitoring, based on bioassays, show that sensitivity has remained in the range of previous years.

In 2014/15, the mutation F129L has been found in the majority of the samples throughout Brazil and Paraguay at high levels, which can lead to reduced sensitivity. High frequency of this mutation may affect field performance, therefore QoI must be applied with a robust partner (the multi-sites/protectants, exclusively applied together with a QoI, provide control for a limited period and, after that, may leave the QoI unprotected and may endanger sound resistance management).

In 2015/16 a similar high level situation has been observed as described in 2014/15.

High frequency of F129L mutation has been observed in season 2016/17 as known from previous years and has been confirmed now also for Bolivia, Paraguay and on volunteer soybean plants.

High frequency of F129L mutation has been observed in season 2017/18 as known from previous years and has been confirmed now also for Bolivia, Paraguay and on volunteer soybean plants.

High frequency of F129L mutation has been observed in season 2018/19 as known from previous years in Brazil.

(Analysis of historic samples showed that the F129L mutation was present at significant levels from at least 2012/13).

Additional information: As already observed with other pathogens, resistance factors resulting from the F129L mutation are significantly lower in comparison with the G143A mutation.

(see FRAC document titled “Mutations associated with QoI resistance” available on the FRAC website under QoI fungicides →Quick references).

No samples containing the G143A mutation have been found in this pathogen. These findings are consistent with the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur (see FRAC QoI Intron Document).

Target Spot (*Corynespora cassiicola*)

Companies: BASF, Syngenta

No monitoring performed in 2017 and 2018.

Findings:

Resistance due to the G143A mutation was detected in a significant high number of samples from Brazil in 2015 and 2016

Resistance due to the G143A mutation was detected at high frequency in all 7 monitored Brazilian states (MT, MS, GO, BA, MG, PR, TO) in 2018/19 season.

2.1.7. Other crops

Vegetables

Cucumber downy mildew (*Pseudoperonospora cubensis*)

Companies: Syngenta

Findings:

Single isolates/samples from France, Greece, Italy, Poland and Spain were monitored as resistant in 2019.

Previous monitorings showed the following:

Monitoring in the East Coast of USA showed widespread presence at high frequency of resistance in 2013.

2014: Resistance was found in samples from cucumber in Greece, Italy (Sicilia) and Spain. Samples from melons collected in Italy (Piemonte) were sensitive. (Bayer, Syngenta).

A limited monitoring program was carried out in China in 2017. The resistance allele (G143A) has been detected in five different provinces.

Alternaria spp.

Companies: Syngenta

Monitoring: Monitoring has been carried out on carrots, cabbages, cauliflower and broccoli in 2019.

Alternaria dauci:

Findings:

Single isolates/samples from Italy and Hungary were monitored as resistant.

Previous monitorings showed the following:

Results showed that resistance in *A. dauci* from carrots is present at no to low level in Bulgaria, Croatia, Germany, Italy, Netherlands and Portugal.

Full sensitivity has been found in Denmark, France, Lithuania, Poland, Spain and Sweden.

Alternaria brassicicola:

Findings:

All samples from 2019 were sensitive: Belgium, Croatia, France and Spain (Cauliflower, broccoli)

Alternaria brassicae:

Findings:

All samples from 2019 were sensitive: Belgium, Croatia, France and Spain (Cauliflower, broccoli, cabbages).

Spinach

Stemphylium botryosum

Companies: Syngenta

Findings:

Monitoring for 2019 is ongoing.

Resistance has been detected in 2018 in Florida (USA) based on a limited number of isolates

Soft fruits

Gray Mold (*Botrytis cinerea*)

Companies: Bayer

Findings:

Strawberries: 2019 monitoring in Germany, Poland and United Kingdom showed high frequency of resistance and moderate frequencies in Denmark and France.

Previous monitoring showed the following:

Monitoring in 2017 has been carried out and showed high resistance frequencies in Denmark, Germany, France, Poland, Sweden and United Kingdom.

In 2018:

Monitoring in 2018 showed high resistance frequencies in Denmark, Germany, Norway, Poland, Sweden and United Kingdom, while the resistance frequency was low in a limited number of French samples.

Grapes

Gray Mold (*Botrytis cinerea*)

No monitoring done in 2019

Companies: Bayer

Findings:

In 2015:

High frequencies of resistance strains were found in Chile and Germany.
Medium frequency in France.
Low in Italy.

In 2016:

In 2016 similar situation as in 2015 in Chile.
In Italy low levels and in Germany and France moderate resistance levels were detected in 2016.

In 2017:

High levels in Germany.
Remaining moderate levels in France.
Low to moderate levels of resistance in Italy.

In 2018:

High frequency was detected in Germany, while low frequency was found in Italy

Additional information: QoI sensitive (cyt b wild type) strains often could be divided in isolates carrying or not carrying the intron in the cytochrome b gene. (Add link to intron (see FRAC document titled “Mutations associated with QoI resistance” available on the FRAC website under QoI fungicides (link)).

Oilseed Rape (Canola)

Stem Rot (*Sclerotinia sclerotiorum*) OSR

Companies: Sumitomo, Syngenta

Findings:

In 2019 full sensitivity has been monitored as in previous years in Czech Republic, Germany, France, Hungary, Poland, Romania, Slovakia and Ukraine

Previous monitorings showed the following:

Monitoring in 2016, 2017 and 2018 from Czech Republic, Hungary, Denmark, France, Germany, Latvia, Lithuania, Poland, Romania, Sweden, Ukraine and United Kingdom Slovakia and Bulgaria showed a fully sensitive situation with no target site mutations detected.

Additional information: Sporadic cases of reduced sensitivity observed in lab studies underlines the need to use inhibitors of the alternative oxidase (AOX), such as SHAM

or propyl-gallate, in sensitivity tests. Relevance of the AOX in practice needs further elucidation.

Blackleg (*Leptosphaeria maculans*, *L. biglobosa*)

Companies: BASF

Findings:

In 2018/19 full sensitive situation were found in samples from Czech Republic, Croatia, Germany, France, Poland, Slovakia and United Kingdom.

Previous monitorings showed the following: Monitoring carried out in 2017/18 in Czech Republic, Germany, France, Poland and United Kingdom showed a fully sensitive situation.

So far, no resistant isolate has been found in any country.

Sunflower

White Mould (*Sclerotinia sclerotiorum*)

No monitoring was carried out in 2019

Companies: BASF, Corteva

Findings:

Monitoring carried out in Hungary and Slovakia in 2016 and 2018 showed a fully sensitive situation.

Corn

***Pythium* spp.**

Companies: Syngenta

Findings:

In 2019

In samples collected in 2019 from Belgium, Germany, France, Hungary, Italy, Romania, Spain and United Kingdom G143A mutation was not observed in otherwise naturally sensitive *Pythium* species.

Sugar Beet (*Cercospora beticola*)

Companies: BASF, Bayer, Syngenta

Findings:

In 2019:

High levels were detected in: Austria, Belgium, Denmark, France, Italy, Netherlands, Slovakia and Switzerland, Czech Republic

Moderate to high in: Hungary, Poland and Romania

Low to high in: Germany, Russia, Ukraine and Turkey

Single isolates/sample with resistance were found in Slovakia and Spain

Low in Lithuania

Previous monitorings showed the following:

The levels of resistance found in 2017 and 2018 were:

High levels: Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Romania, Serbia, Slovakia, Switzerland, Ukraine and United Kingdom.

Moderate to high levels: France, Poland.

In Denmark, Germany, Turkey, Romania and Russia a more heterogeneous situation across the country ranging from no to high levels were found.

Low to moderate levels: Lithuania.

Additional information: Information for previous years is given in the 2017 minutes.

Gummy stem blight (*Didymella bryoniae*)

Company: Syngenta

In 2019 full sensitivity was monitored in Belgium.

Single isolates/samples showing resistance with presence G143A were monitored in Spain.

Rice

Blast (Pyricularia oryzae = Magnaporthe oryzae)

No monitoring carried out in 2019.

Companies: BASF, Syngenta

Findings:

Monitoring results from Japan between 2013 and 2016 showed a decrease of resistance frequency-, following a reduced use of QoI. Resistance, based on G143A presence has been confirmed in Vietnam with heterogeneous frequency from zero to high in 2017 similar as observed as in 2016.

No resistance was detected in Indonesia (2016), China (2017), India (2015) and the Philippines (2016).

Monitoring was carried out in Spain and Italy in 2016 and showed full sensitivity. No resistance has been detected so far in Europe.

No to high: High heterogeneous distribution of QoI resistance was monitored in certain region of Vietnam in 2018 as in the previous years.

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

No monitoring was carried out in 2019.

Companies: Syngenta

No monitoring performed in 2018.

Findings:

Full sensitivity was monitored in 2014 and 2015 in China and in 2015 in Japan.

Low: Samples in 2011 from a small number of fields in Louisiana, USA were found to contain less sensitive isolates. Monitoring carried out between 2012 and 2017 showed a stable situation. Only the F129L mutation has been found in these isolates.

Additional information: For further known cases of QoI resistance, see the document titled "Species with QoI Resistance (2012)" on the FRAC website located under QoI fungicide (link).

2.1.7. Resistance information for pathogens not regularly monitored

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

No monitoring was carried out in 2019.

Findings:

No to low: During sensitivity studies with *Puccinia hordei* during 2010 to 2014, occasional isolates with slightly higher EC50 values to Qols have been detected in Denmark, France, Germany, Sweden, and United Kingdom (in 2014 only in Denmark, France, and United Kingdom).

Situation in 2018 is similar as found in 2014.

Additional information: However, resistance factors are low and the mutations normally associated with Qol resistance were not found.

The practical relevance of these findings is considered to be minor. The mechanism is not known, no relevant mutations have been found.

Field performance in 2018 of Qol containing spray programs was good.

Apple Powdery Mildew (*Podosphaera leucotricha*)

No monitoring was carried out in 2019.

Companies: BASF

Monitoring: No data for 2017 and 2018 were presented.

Findings:

In 2016, resistance has still not been detected as in previous years in Czech Republic, France, Germany, Greece, Italy, Netherlands, Poland, Portugal and Spain. Field performance has been good.

Additional information: These findings are most likely to be related to the reported presence of a lethal intron in several fungi making the G143A mutation unlikely to occur (see FRAC document titled “Impact of Intron at G143A on Qo resistance development” located on the FRAC website under Qo fungicides → Quick references).

Information for previous years is given in the 2017 minutes.

Alternaria alternata

No monitoring was carried out in 2019.

Companies: Syngenta, Corteva

Monitoring: No monitoring in 2017 and 2018, Data below are from 2016

Findings:

Tomato

Limited monitoring is carried out in 2016.

Resistance has been found in Bulgaria, Greece, Italy and Poland.

Potato

Resistant isolates (bearing the G143A mutation) were found in potato samples from Belgium, Bulgaria, France, Germany, Hungary, Netherlands, Poland, Romania, Slovakia, Sweden and United Kingdom at medium levels.

No mutation was found in Spain.

Cucumber powdery mildew (*Sphaerotheca fuliginea*= *Podosphaera xanthii* and *Golovinomyces cichoracearum*)

Companies: Bayer, (Syngenta)

No monitoring performed in 2018 and 2019.

Findings:

Monitoring was carried out in China during 2014. The frequency of resistance found was high.

No Monitoring was carried out in 2015 and 2016.

Testing of a few samples in 2017 confirmed presence of resistance in Italy and Spain from cucumber and zucchini ranging from no to high frequency.

Lettuce (*Bremia lactucae*)

Companies: BASF

No monitoring performed in 2017 and 2018 and 2019.

Findings:

No resistance: In 2016 genetic analysis showed that all samples from Spain and Germany did not contain any known mutations potentially causing QoI resistance and were therefore classified as sensitive to QoI.

Onion (*Peronospora destructor*)

Companies: BASF

No monitoring performed in 2017 and 2018 and 2019.

Findings:

No resistance: In 2016 genetic analysis showed that samples from Germany did not contain any known mutations potentially causing QoI resistance and were therefore classified as sensitive to QoI.

Potato

Black scurf (*Rhizoctonia solani* AG1.1A)

Companies: Syngenta

No monitoring performed in 2018 and 2019.

Findings:

In 2017 less sensitive isolates were detected in China (Inner Mongolia, Hebei, and Gansu) at low frequency.

Low: In 2016 a small number of fields in Louisiana, USA were found to contain less sensitive isolates.

Peas and Beans

White Mould (*Sclerotinia sclerotiorum*)

Companies: BASF

No monitoring performed in 2018 and 2019.

Findings:

No resistance: Monitoring carried out in 2017 in France, Germany and Poland showed full sensitivity.

2.2. Review of global guidelines

2.2.1 QoI – General Strategies and Guidelines for the 2020 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, mandestrobin, metominostrobin, oryastrobin, 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 (refer to the specific crop recommendations).
- 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 QoI – Specific Crop/Pathogen guidelines

2.2.2.1. QoI – Strategies and Guidelines for cereals

Where the guidelines 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, multi-sites) 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 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 manufacturer's 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 QoI – Vine diseases

General Guidelines for using QoI fungicides on vines:

Apply a maximum of 4 QoI fungicide containing sprays against any disease per vine crop, and a maximum of 33% of the total number of applications.

QoI – 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 2 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

QoI – 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 QoI – Pome fruit diseases

Guidelines for using QoI fungicides on pome fruits

QoI – 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 QoI – Potato and tomato diseases

Guidelines for using QoI fungicides on potatoes and tomatoes

QoI – 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 of 6 QoI fungicide applications whichever is the lower. Do not use more than 3 consecutive QoI fungicide containing sprays.

QoI – 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. Where resistance has been confirmed, QoI fungicides must be applied only in mixture with partners contributing to the effective control of the target pathogens.

2.2.2.5 QoI – Guidelines for use on soybean diseases

QoI fungicides control soybean diseases including rust, which is a major disease in Latin America and has been detected recently in the USA.

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

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.

1. Use QoIs preventatively or as early as possible in the disease cycle.
2. Use QoIs preferably in mixtures (co-formulations or, where permitted, 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. In regions where target site mutations in key target soybean pathogens are present mixtures are mandatory.
3. Limiting the number of sprays containing QoI fungicides is an important factor in delaying the build-up of resistant pathogen populations.

Good agricultural practices must be considered to reduce source of inoculum, disease pressure and resistance risk, e.g. no multiple cropping, implement and respect soybean-free periods, consider varietal tolerance, reduce the planting window, give preference to early-cycle varieties or endorse the destruction of volunteers.

2.2.2.6 QoI – Guidelines for use on sugar beet

QoI – *Cercospora beticola*

1. Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stages indicated. 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 from a different cross-resistance group, contributing to the effective control of the target pathogens.
3. Apply QoI fungicides preventatively. Under high disease pressure the spray interval should not be extended.
4. Do not exceed 50% of the total number of sprays with QoI containing products. In low disease pressure situations where only 1 fungicide application is required

for disease control then a QoI – containing mixture (as defined above) may be used.

Where QoI fungicides are used targeting other sugar beet diseases (e.g. rust, powdery mildew, *Rhizoctonia*, *Ramularia* and *Stemphylium*) then the potential impact of applications on the resistance management of *Cercospora beticola* should be considered. Where *Cercospora beticola* is not a disease of importance (e.g. in a certain geography) then the general guidelines for QoI fungicides apply.

2.2.2.7 QoI – 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.

2.2.2.8 QoI – Guidelines for use in 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.

2.2.2.9 QoI – Guidelines for use in 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:

- i. 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.
- ii. 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.
- iii. 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.

2.2.2.10 QoI – Guidelines for use on Rice

Rice Blast (*Pyricularia oryzae*, *Magnaporthe oryzae*)

1. Apply a maximum of 2 foliar treatments per season.
2. In situations where resistance has been detected or the risk is considered to be high always apply QoI fungicides in mixtures (where permitted) with non-cross resistant fungicides. At the chosen rate, the respective partner(s) on its/ their own

has/ have to provide effective disease control. Refer to manufacturers recommendations for rates.

3. Apply QoI fungicides in programs with fungicides of different mode of actions.
4. Avoid QoI fungicides for seed production.
5. Apply QoI fungicide based products at effective rates and intervals according to manufactures' recommendations.
6. To keep good field sanitation, avoid transplanting diseased seedlings, remove or destroy primary infection source e.g. left-over seedlings, infested straw and chaff.

QoI – Seed treatment applications in Rice

QoIs are and will be used as seed treatment products.

It is FRAC's objective to protect this fungicide group and integrate all uses into technical recommendations. These minutes contain a recommendation on seed treatments, including those which have efficacy on foliar pathogens.

These recommendations will be reviewed regularly and supported by monitoring. When an QoI fungicide is used as a seed treatment on rice, there should be no implications regarding QoI FRAC guidelines on the use of foliar QoI fungicides on the same crop as long as the QoI seed treatment is directed by rate and efficacy against seed and soil borne diseases or 'low risk' foliar pathogens (Link to FRAC pathogen risk classes).

QoIs used as a seed treatment in rice providing foliar efficacy against pathogens with moderate/ high resistance risk count against the total number of QoI applications.

If QoI seed treatment has been used, first foliar application have to be made with a different mode of action in the vegetative phase before subsequent QoI-based foliar sprays in the reproductive phase.

Please refer to the recommendations of Japan-FRAC www.jfrac.com link

2.2.2.11 QoI – 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 2018 meeting of the FRAC Banana Working Group are available on the FRAC Website (<http://www.frac.info/>). The next meeting of the group was moved to autumn 2020 due to the Covid-19-situation.

2.2.2.12 QoI – Other crops and pathogens

Crops and pathogens not covered above with a specific recommendation, follow the general guidelines (2.2.1).

3. Communication plans

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

4. Next meetings:

All crops:

Next regular meeting in January 21st, 2021.

Venue: Frankfurt

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