Quinone 'outside' inhibitor (QoI) Working Group

Meeting on January 25th and 26th, 2021, each 8:30 am - 12:30 am
Protocol of the discussions and use recommendations of the QoI Working Group of the Fungicide Resistance Action Committee (FRAC)

Participants

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Companies participating in the meetings:
BASF, Bayer, FMC, Corteva, Syngenta, Sumitomo

QoI working group of FRAC
Minutes of the meeting
All crops: January 25th and 26th, 2021

Updated on March 3rd, June 23rd, September 15th and November 29th 2021
held in virtually

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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, separated into two subgroups reflecting different binding properties (FRAC codes 11 and 11A)

The QoI FRAC code 11 fungicides are: azoxystrobin, coumoxystrobin, dimoxystrobin, enoxastrobin, famoxadone, fenamidone, fenaminostrobin, fluoxastrobin, flufenoxystrobin, kresoxim-methyl, mandestrobin, metominostrobin, orysastrobin, pyraoxystrobin, picoxystrobin, pyraclostrobin, pyrametostrobin, pyribencarb, triclopyricarb, trifloxystrobin

QoI FRAC code 11A fungicide is: metyltetraprole

Fungicides within each code group are all cross-resistance to each other and should be managed accordingly. Fungicides in the code group 11A are not cross resistant to fungicides in the FRAC code group 11 based on the G143A mutation.

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.

Fungicides in FRAC code 11:

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 and rye (*Blumeria graminis f. sp secalis*)

Companies: BASF, Bayer

Monitoring based on molecular data in 2020 for samples collected from wheat showed low to moderate frequency of G143A BG, moderate in HU, CZ and high in PL.

Samples collected from rye in 2020 from PL were all sensitive, based on molecular analysis.

Findings in 2019:

Monitoring has been carried out in Czech Republic, Latvia, Lithuania and Poland with medium to high frequencies of resistance.

Low to medium were reported in Czech Republic.

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

Companies: BASF, Syngenta

Monitoring data based on molecular data showed in 2020 the following situation:

In France, Germany, Denmark, Ireland, Latvia, Lithuania, Sweden, and United Kingdom widespread resistance over all these countries at high levels were detected.

Medium to high resistance level was detected in Croatia, Czech Republic and Poland.

In Austria, Italy, Spain, Switzerland and Ukraine populations were showing in average moderate levels of resistance with high variability.

Low to moderate levels were reported in Hungary, Romania, Russia, Slovakia and Ukraine.

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

Limited monitoring based on molecular analysis from 2019 showed high frequency of G143A in New Zealand.

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

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: BASF, Bayer and Syngenta

The monitoring in 2020 based on bioassay confirmed the sensitive situation reported already in previous years.

Countries tested included Denmark, France, Germany, Hungary, Poland and United Kingdom.

In 2020, performance of QoI fungicides against brown rust was good.

Findings in 2019:
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 and Syngenta

The monitoring in 2020 based on bioassay confirmed the sensitive situation reported already in previous years.

Countries included: Belgium, Denmark, France, Germany, Poland, Spain, United Kingdom.

Findings from 2019:
All isolates tested from Belgium, Germany, Denmark, Latvia, Sweden and United Kingdom were sensitive.

***Rhizoctonia solani*, wheat**

Companies: Syngenta

In 2020 limited monitoring data based on bioassay showed full sensitivity in Germany and Spain.

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

No monitoring in 2020

Companies: Bayer

Limited monitoring in 2019

Findings:
No to Low in Latvia and Lithuania.

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

Net blotch (*Pyrenophora teres*), barley

Companies: BASF, Bayer, Syngenta

Field performance of QoI-containing fungicides against net blotch was good.

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.

Monitoring in 2020 based on bioassay and molecular studies showed the following situation:

Medium to high levels were found in Belgium, Germany, Ireland, Netherland and United Kingdom.

Medium levels were detected in Denmark, France, Lithuania, Sweden, Switzerland and Poland.

No to low levels were reported in Austria, Hungary, Italy, Latvia, Poland, Romania, Russia, Slovakia, Spain and Ukraine.

No resistance of mutation was found in Bulgaria, Czech Republic and Greece.

The situation in 2019 was as follows:

Medium to high in Denmark

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 break-down 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 and Syngenta

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

In 2020 monitoring based on bioassay and molecular studies showed full sensitivity in Denmark, Germany, France, Hungary, Ireland, Latvia, Netherland, Poland, Slovakia, Spain and United Kingdom.

Findings in 2019:
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

Monitoring in 2020 based on molecular studies measuring frequency of G143A, F129L and G137R and bioassay data showed the following situation.

High levels of resistance were detected in Denmark, Hungary and Latvia,

moderate to high in Poland,

moderate in Germany,

low in Austria, Czech Republic, Romania and Ukraine and

no resistance detected in B.

Single resistant samples/isolates were found in Russia and Sweden.

Findings in 2019:

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

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

Companies: BASF, Syngenta

Monitoring in 2020 based on bioassay and molecular quantification G143A showed the following results.

High frequency of resistance was found in Czech Republic, Denmark, Hungary, Ireland, Latvia, Slovakia, Sweden and United Kingdom,

moderate to high frequency in Germany and France,

moderate frequency in Switzerland and

low frequency in Spain.

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

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

Companies: Bayer, Syngenta

In 2020 monitoring data based on bioassay showed full sensitivity in Denmark, France, Germany und United Kingdom.

No monitoring was carried out in 2019.

No to low: During sensitivity studies with *Puccinia hordei* during 2010 to 2014, occasional isolates with slightly higher EC50 values to QoIs 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 QoI 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 QoI containing spray programs was good.

2.1.2. Vine diseases

Downy mildew (*Plasmopara viticola*)

Companies: BASF, Corteva and Syngenta

Monitoring in 2020 is ongoing. Preliminary results show a stable situation with a tendency to lower frequency of G143A in many European populations.

The frequency of G143A mutation has been studied in the following countries:

Moderate to high frequency was reported in Greece and Turkey,

moderate frequency in Germany,

low to high frequency in Hungary and

low to moderate frequency was reported in Austria, Italy, Portugal and Spain.

No monitoring was carried out in 2019.

Companies: BASF, Syngenta, Corteva

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) were detected.

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

Medium levels were reported 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 were found 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, Bayer, Syngenta

Data from bioassay and molecular studies were presented. The levels of resistance found in monitoring programmes in 2020 are summarised below:

High levels were reported from Austria, Croatia, France (Champagne, Bourgogne, Bordeaux, Languedoc-Roussillon), Greece, Northern Italy,

moderate to high levels from Germany, France (Loire), Hungary and Slovenia,

moderate: France (Rhone),

low to moderate in Italy (Emilia Romagna, Marche, Toscany) and

no to low levels were reported in Spain.

Depending on the location sampled results indicated no to high frequency of resistance in Turkey and Portugal.

Findings in 2019:

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

Moderate levels were detected in France (Loire), Germany (Mosel), Italy (Emilia Romagna, Marche, Toscany)

Low to moderate France (Rhone (low) and Val de Loire (moderate)

No to high in Turkey

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

2.1.3 Pome fruit diseases

Apple scab (*Venturia inaequalis*)

Companies: BASF, Bayer

Disease information: Disease pressure in 2020 was low to 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.

Molecular data has been generated in 2020 season in order to identify the mutation G143A.

High frequency was found across Germany and France with a few regional exceptions

In 2019 the results were as indicated below:

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

Medium in France

Heterogeneous situation found in Spain from zero to high levels.

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

Samples from India (Kashmere) were all sensitive.

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

Apple Powdery Mildew (*Podosphaera leucotricha*)

No monitoring was carried out in 2019 and 2020.

Companies: BASF

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 QoI fungicides → Quick references).

Information for previous years is given in the 2017 minutes.

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

Companies: BASF

In 2020: Genetical analysis showed again a higher frequency of *M. fructicola* and *M. laxa* compared to *M. fructigena.*

No resistance based on bioassay were found in Greece, Germany, France, Hungary, Italy, Poland, Portugal and Spain.

Findings until 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

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 2016 no resistance was detected in samples from France, Greece, Hungary, Italy and Poland.

Monitoring data for 2014 and 2015 showed all populations to be fully sensitive (France, Greece, Hungary, Italy, Poland and Spain) (BASF, Bayer).

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)).

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

No data was reported in 2020

Companies: Syngenta

Findings in 2019:
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* (bulls eye rot), apples**

No monitoring was carried out in 2019 and 2020

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*)

Companies: BASF

In 2020 bioassay tests showed no resistance in all isolates collected in 2020 from potato crops in Czech republic, France, Netherlands, Poland, Portugal, Spain and Turkey.

Early blight (*Alternaria* spp.)

Alternaria solani

Companies: BASF, Bayer, Syngenta

Monitoring based on bioassay and molecular studies were carried out in potatoes (*Alternaria solani*) in Europe in 2020.

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 and Sweden,

moderate frequency was detected in Belgium, Germany, Netherlands and Norway.

Less sensitive isolates were found at low frequency in samples from Serbia.

Monitoring carried out in potatoes (*Alternaria solani*) in Europe in 2019 showed the following situation:

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)).

Alternaria alternata on potato and tomato

No monitoring was carried in 2020

Companies: Syngenta, Corteva

No monitoring in 2017 and 2018

Data below are from 2016

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.

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

Companies: Syngenta

No monitoring performed in 2018, 2019 and 2020.

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.

2.1.6. Soybean diseases

Asian Rust (*Phakopsora pachyrhizi*)

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

Findings:

High frequency of F129L mutation has been observed in season 2020/21 as known from previous years in Brazil.

High frequency of F129L mutation has been observed in season 2019/20 as known from previous years in Brazil.

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

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 2016/17 as known from previous years and has been confirmed now also for Bolivia, Paraguay and on volunteer soybean plants.

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

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 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.

(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

Monitoring was performed in season 2020/21

High frequency and widespread presence of mutation G143A across Brazil has been reported.

Monitoring was performed in season 2019/20.

High frequency and widespread presence of mutation G143A across Brazil has been reported.

Findings until 2016:

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.

Cercospora leaf blight (*Cercospora* spp.)

Companies: Corteva, Syngenta

Initial monitoring showed high frequency of mutation G143A across Brazilian regions in season 2019/2020

2.1.7. Other crops

Vegetables

Cucumber downy mildew (*Pseudoperonospora cubensis*)

Companies: Syngenta

Single samples from zucchini and cucumber tested by bioassay from France, Germany, Greece, Italy, Poland, and Spain were monitored as resistant in 2020.

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.

***Corynespora cassiicola* from cucurbits**

Companies: BASF

Sensitivity tests based on bioassay and molecular data from China (Guangdong) in 2020 showed high frequency of QoI resistance.

Cucurbits - Gummy stem blight (*Didymella bryoniae*)

Company: Syngenta

No monitoring in 2020

In 2019 full sensitivity was monitored in Belgium.

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

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

Companies: Bayer, (Syngenta)

No monitoring performed in 2018, 2019 and 2020.

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.

***Alternaria* spp. on various vegetables**

Companies: Syngenta

Monitoring 2020 is ongoing.

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

Alternaria dauci:

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*:**

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

Alternaria brassicae:

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

Spinach

Stemphylium botryosum

No data were reported for 2020.

Companies: Syngenta

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 based on frequency of G143A mutation in molecular tests in 2020:

For strawberries monitoring in 2020 showed in Germany, France, Italy, Poland and United Kingdom high frequency of resistance and moderate frequencies in Norway.

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 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.

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

Grapes

Gray Mold (*Botrytis cinerea*)

No monitoring done in 2019 and 2020.

Companies: Bayer

In 2018:
High frequency was detected in Germany, while low frequency was found in Italy

In 2017:
High levels in Germany.
Remaining moderate levels in France.
Low to moderate levels of resistance 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 2015: High frequencies of resistance strains were found in Chile and Germany.

Medium frequency in France.
Low 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. (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: BASF, Sumitomo and Syngenta

Monitoring 2020 is ongoing.

Findings based bioassays in 2020 showed full sensitivity in Austria, Bulgaria, Czech Republic, Germany, France, Hungary, Latvia, Lithuania, Poland, Romania, Ukraine and United Kingdom.

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

Previous monitoring 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 (*Plenodomus lingam, P. biglobosus, syn.: Leptosphaeria maculans and L. biglobosa*)

Companies: BASF

Findings based on bioassays in 2019/20:

Full sensitivity was found in France, Germany, Poland and United Kingdom for both species. As in the previous years *P. lingam* was more frequently detected than *P. biglobosus*

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

Previous monitoring 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.

Light leave spot on OSR (*Pyrenopeziza brassicae*)

Companies: BASF

Initial monitoring in 2020 from United Kingdom indicates full sensitivity based on bioassay.

Sunflower

White Mould *(Sclerotinia sclerotiorum)*

Companies: BASF, Corteva

Findings based on bioassay of isolates from 2019 showed a fully sensitive situation in Bulgaria, Romania and Slovenia.

Lettuce Downy Mildew (*Bremia lactucae*)

Companies: BASF

No monitoring performed in recent years.

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 Downy Mildew (*Peronospora destructor*)

Companies: BASF

No monitoring performed in recent years.

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.

Beans and green beans and lettuce

White Mold, *Sclerotinia sclerotiorum*

Companies: BASF, Syngenta

Monitoring based on bioassay of samples from 2019 and 2020 from France (beans and green beans) and Spain (lettuce) showed full sensitivity.

Monitoring carried out in 2017 in France, Germany and Poland showed full sensitivity.

Corn

***Pythium* spp.**

Companies: Syngenta

Monitoring based on bioassay form strains collected in 2020 from Netherland, Italy, Romania, Spain and United Kingdom indicates full sensitivity.

Tested Pythium species are: *P. attrantheridium*, *P. heterothallicum*, *P. lutarium*, *P. sylvaticum* and most strains of *P. ultimum*. Some strains of *P. ultimum* were reported in the past to be tolerant to QoI fungicides, however, in these strains no G143A mutation was found.

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.

Exserohilum turcicum, Setosphaeria turcica **(Northern leaf blight, corn)**

Companies: BASF

Monitoring data based on bioassay from 2018 and 2019 from France, Germany and Italy showed full sensitivity.

Bipolaris spp **(Northern leaf spot; *Cochliobolus heterostrophus,* corn)**

Companies: BASF

Monitoring data based on bioassay from 2019 from various locations in Italy showed full sensitivity.

Sugar Beet

Cercospora leaf spot (*Cercospora beticola*)

Companies: BASF, Bayer, Syngenta

In 2020, findings based on molecular studies showed high frequency of G143A in Belgium, Czech Republic, Denmark, Germany, France, Hungary, Italy, Lithuania, Netherland, Switzerland, Ukraine and United Kingdom. Moderate to high frequency were detected in Spain, moderate in Poland and low to moderate in Romania.

Findings until 2019:

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

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 Russia, 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.

Rice

***Blast* (*Pyricularia oryzae = Magnaporthe oryzae*)**

Companies: BASF, Bayer and Syngenta

In 2020, monitoring data based on molecular studies showed overall low to moderate frequency of G143A in nine provinces of Vietnam. Comparing different locations frequency of G143A varied from no to high. The 2020 results indicate a stable situation compared to previous years.

Monitoring data based on molecular studies performed in China in 2019 and 2020 showed full sensitivity.

No monitoring carried out in 2019.

Findings until 2018:
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 2018, 2019 and 2020.

Companies: Syngenta

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).

Cotton

Ramularia leaf spot (*Ramulariopsis pseudoglycines*, syn. *Ramularia areola*)

Companies: BASF

Monitoring in 2020/21 on country level in Brazil showed high frequency of resistance in bioassay.

Monitoring studies for season 2019/20 are running. Monitoring performed with isolates from the seasons 2017/18 and 2018/2019 showed high frequency of QoI-resistance in Brazil.

Fungicides in FRAC code 11A

Result sharing is planned in time before the product is available for use

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, orysastrobin, pyraoxystrobin picoxystrobin, pyraclostrobin, pyrametastrobin, pyribencarb, triclopyricarb trifloxystrobin) are in the same cross-resistance group; ; FRAC Code 11
- The QoI fungicide in subgroup A (metyltetraprole), Code 11A fungicide, is not cross resistant with Code 11 fungicides in pathogens with G143A mutation.
- 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.
- Limitation of the total number of QoI applications is detailed in the specific crop recommendations. In consideration of the cross-resistance profile of subgroups 11 and 11A, the maximum allowed number of QoI-containing sprays is increased by one, where both QoI fungicides (code 11) and QoI fungicides in subgroup A (code 11A) are included in a spray program in a given cropping season. All crop-specific recommendations will be regularly reviewed based on sensitivity monitoring.
- A consequence of limitation of QoI fungicide based products is the need to use it in a spray program with effective fungicides from different cross-resistance groups (refer to the specific crop recommendations).
- QoI products, containing only the solo QoI fungicide, should be used in single or block applications in alternation with fungicides from a different cross-resistance

group. Specific recommendation on the number of consecutive treatments (size of blocks) is 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 (including two-way mixtures of code 11 fungicide and code 11A fungicide) 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 QoI – Specific Crop/Pathogen guidelines

Specific crop recommendations for FRAC code group 11 A will be prepared in the FRAC QoI working group before the product is available for use.

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 f or rates.
2. The maximum number of QoI-containing sprays is 3, but only when QoI fungicides belonging to both QoI Groups (code 11 and 11A) are included in a spray program. QoI fungicides belonging to the individual Codes (11 or 11A) should not be applied more than 2 times either individually or when mixed together.
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*, *Ramulari*a 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

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 (https://www.frac.info/frac-teams/working-groups/banana-group/recommendations-for-bananas). The next meeting of the group is planned for spring 2020.

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 is planned for 20th of January, 2022

Update meetings are planned for the 7th of April and 21st-22nd September 2022

Venue: virtually and or f2f in Frankfurt

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