

SDHI
Working Group

FRAC
FUNGICIDE RESISTANCE
ACTION COMMITTEE

Succinate Dehydrogenase Inhibitor (SDHI) Working Group

10th Meeting on December 13, 2017

Telephone conference on March 28, 2018 and June 18, 2018

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

Participants

BASF Kristin Klappach (Chairwoman)
Raffaello Zito
Rosie Bryson
Gerd Stammler
Martin Semar

Bayer Andreas Mehl
Dominique Steiger
Juergen Derpmann

Du Pont Jean-Luc Genet
Olivier Couery

Syngenta Helge Sierotzki
Steve Dale
Stefano Torriani
Odile Rambach

Isagro Luca Fusarini
Federico Simonetta

FMC Joachim Duus
Mamadou MBoup

Venue:

Lindner Hotel & Conference Centre, Frankfurt/ Main, Germany

1. Monitoring Results 2017 (FRAC members)

1.1 Cereal diseases

Wheat – Septoria leaf blotch (*Mycosphaerella graminicola*)

(Bayer, Syngenta, BASF, DowDuPont, Isagro/ FMC, Sumitomo)

Disease pressure in 2017 was moderate but regionally variable. Field performance of SDHI fungicides against Septoria was good.

In 2017, sensitivity data for roughly 2.500 isolates were presented from a broad range of countries. The majority of isolates was sensitive; a few showed slightly reduced sensitivity. These isolates, showing low resistance factors, were detected at higher frequency in Ireland and at low frequency in North-Germany, United Kingdom, Netherlands, New Zealand and even lower in France. Such strains were not detected in Ukraine, Poland, Slovakia, Czech Republic, Italy, Spain, Denmark, Sweden, Latvia, Lithuania, Switzerland, Croatia, Greece, Romania, Russia and Tunisia. These isolates are mainly associated to the following mutations: B-T268I/A, B-N225I, B-R265P, C-T168R, C-T79N/I, C-R151S/T/M, C-N86S/A, C-W80S, C-V166M, D-I50F, D-M114V. Single isolates with moderate resistance factors and bearing the mutation H152R (SDH subunit C) were detected in 2017 again in Ireland and the United Kingdom and for the first time in Germany. The overall frequency of this mutation remains at a low level at the European level. The following mutations were also reported but are not associated with any sensitivity change: C-N33T, C-N34T.

Historical background:

Extensive monitoring programs were carried out since **2003**. Most isolates tested in routine monitoring programs were sensitive, within the baseline. Since **2012**, few isolates with reduced sensitivity were detected in Germany, France, Ireland and the United Kingdom (SDH subunit C: T79N, W80S, N86S, SDH subunit B: N225T, T268I). The resistance factors were low and field performance was not affected.

In **2015** and **2016**, single isolates with moderate resistance factors and bearing the mutation H152R (SDH subunit C) were detected in Ireland and the United Kingdom. The mutation was detected for the first time in Italy and the Netherlands in 2016. The overall frequency of this mutation remains at a low level and has not increased at the European level.

The following new mutations with low resistance factors were reported for the first time: B-T268A, B-N225I, C-T79I, C-R151S, C-N86A. The following mutations were also reported for the first time but are not associated with any sensitivity change: C-N33T, C-N34T.

For full details on historical monitoring data, please refer to the archive on the SDHI FRAC WG webpage.

Wheat – Brown rust (*Puccinia recondita*)

(Bayer, Syngenta)

Extensive monitoring programs were carried out since 2005. Samples from the following countries were tested in 2017: Austria, Denmark, Sweden, the United Kingdom, Belgium, France and Germany. All tested isolates were sensitive, within the baseline.

Wheat – Yellow rust (*Puccinia striiformis*)

(Bayer, Syngenta)

In 2017, samples from France, Denmark, United Kingdom, Germany and Latvia were tested and showed full sensitivity, within the baseline.

Wheat – Snow mold (*Microdochium* spp.)

(Syngenta)

Preliminary data from 2016 and 2017 from Belgium, Germany, Denmark, Finland, France, Italy, Lithuania, Latvia, Poland, Russia, Sweden, Ukraine, United Kingdom showed a fully sensitive situation. Monitoring programs carried out in 2015 showed full sensitivity of isolates from Germany, France, the United Kingdom, Slovakia and Italy confirming the results from 2014.

Wheat – Powdery mildew (*Blumeria graminis*)
(BASF, Syngenta)

Monitoring programs carried out in 2017 confirmed the results from previous years and showed full sensitivity of isolates originating from the United Kingdom, France, Belgium, Germany and Denmark, Czech Republic.

Barley – Net blotch (*Pyrenophora teres*)
(Bayer, Syngenta, DowDuPont, BASF)

Disease pressure was moderate to high but regionally variable even within European countries in 2017. Field performance of SDHI-containing fungicides against net blotch was generally good. However, control of net blotch, esp. in areas in France, was difficult in 2017 and potentially related to e.g. the high disease pressure, low varietal diversity, coupled with the break-down of variety-resistance (variety ETINCEL, reference: https://www.arvalis-infos.fr/plugins/WMS_BO_Gallery/page/getElementStream.jspz?id=46981&prop=file) at significant cultivation areas and higher frequencies of mutated strains.

In 2017, the frequency of mutations or insensitive isolates was low in the Czech Republic, Poland, Italy, Lithuania, Greece (trial site), Sweden, Ukraine and Denmark. Moderate frequencies were observed in United Kingdom and Germany but moderate to high in France. Among the mutations with moderately decreased sensitivity, C-G79R and C-H134R are the most frequently detected mutations. In France, C-G79R is the predominating mutation. In United Kingdom, C-H134R is the more frequent mutation. Whereas in Germany, both mutations are found at similar levels.

No mutations or reduced sensitivity were detected in Estonia, Ireland, Hungary, Latvia, Slovakia, Spain, Bulgaria, Romania, Finland and Russia.

These findings emphasize the importance of adhering to FRAC guidelines.

Historical background:

Extensive monitoring programs were carried out since **2003**. Until **2011**, all tested isolates were sensitive, within the baseline. In **2012**, the sensitivity of 2 isolates from North-Germany was outside of the baseline range. A target site mutation was identified in the SDH-B subunit at position 277 (B-H277Y).

In **2013** and **2014**, more isolates were detected with reduced sensitivity, carrying different mutations ([link](#) to mutations table) in France, Italy, Germany and the United Kingdom. The predominant mutation was C-G79R. The resistance factors were low for B-H277Y, D-D124E, D-D145G and moderate for C-G79R, C-H134R, C-S135R, C-N75S, C-R64K, D-H134R, C-K49E. The mutation D-G138V was detected for the first time in **2015** and found to be associated to very low resistance factors.

The sensitivity situation in **2016** was similar to 2015: The frequency of mutations was low in the United Kingdom, Czech Republic, Poland, Italy, Southern France, Southern Germany and Denmark. Moderate frequencies were observed in Northern France and Northern Germany. Among the mutations with moderately decreased sensitivity, CG79R and C-H134R are the most frequently detected mutations. While in France, C-G79R is the predominating mutation, in Germany, C-H134R is observed to be the more frequent mutation.

No mutations were detected in Estonia, Ireland, Hungary, Latvia, Lithuania, Slovakia, Spain, Bulgaria, Romania, Ukraine, Finland, Sweden and Russia (in 2016).

For full details on historical monitoring data, please refer to the archive on the SDHI FRAC WG webpage.

Barley – Scald (*Rhynchosporium secalis*)
(Bayer, BASF, Syngenta)

Disease pressure was very low in 2017. Extensive monitoring programs were carried out since 2003. In 2017, isolates were tested from France, the United Kingdom, Germany, Denmark, Spain, Latvia, Italy, Czech Republic and Poland and were sensitive, within the baseline.

Barley - Ramularia leaf spot (*Ramularia collo-cygni*)
(BASF, Bayer, Syngenta, Isagro/ FMC)

Disease pressure was moderate in 2017.

Preliminary data show no mutations in Finland, Norway, Spain and Greece.

Low frequency has been found in Estonia, Latvia, Italy, Austria, Switzerland, Czech Republic, Denmark and Sweden.

A heterogeneous situation, ranging from low to high (frequency of mutations and sensitivity), was observed in Germany, France, United Kingdom, Ireland and Netherlands.

Significantly decreased sensitivity is mainly associated with the mutations C-G91R, C-H146R/L, C-G171D or C-H153R. Additionally, a mutation linked to lower resistance factors (C-N87S) was detected.

Historical background:

In **2014**, single isolates with slightly decreased sensitivity were detected from France and Germany. Retesting of 2014 isolates showed full sensitivity. Isolates sampled in 2014 from the Czech Republic were sensitive, within the baseline.

In **2015**, extensive monitoring in Germany showed particularly in trial-sites for the first time occurrence of strains with strongly decreased dose-response in bioassays, carrying the mutation C-H146R or C-H153R. Another mutation, C-N87S, which was found to be associated with low resistance factors, was found in Germany, Ireland and Slovenia in single isolates. No mutations were detected in Austria and Croatia.

In **2016**, no mutations were detected in Sweden, Denmark, Estonia, Slovakia, France and Greece.

Samples carrying the mutations C-H146R or C-H153R, associated with significantly decreased sensitivity, were detected in Germany, Ireland, the Netherlands and the UK. Observations in trial sites confirmed the results from 2015. A decreased dose response was observed in field trial sites in Germany and the UK with high proportions of SDHIs in spray programs. Samples taken from the untreated plots at the same sites showed baseline level sensitivity.

Barley – Rust (*Puccinia hordei*)
(Bayer)

Monitoring programs were carried out since 2006. All isolates tested until 2014 were sensitive, within the baseline.

No monitoring was carried out in 2015, 2016 and 2017.

1.2. Grape diseases

Grape grey mold (*Botrytis cinerea*)
(Bayer)

Monitoring in France, Germany and Italy resulted in overall low frequencies of the C-P225.. mutations. The C-P225F and C-N230I-mutations were found to be slightly increased in Germany.

Historical background:

Extensive monitoring programs were carried out since 2003.

In **2012**, few isolates with resistance to SDHs were detected in France and Germany.

An increasing frequency was observed in Germany in **2013**. No new mutations have been identified in **2014** and the percentage of less sensitive isolates remained stable compared to 2013.

In **2015**, resistant isolates were detected in Germany, France, Italy, Portugal and Chile at low frequency.

In **2016**, samples were tested coming from Spain, France, Germany, Austria, Hungary, Italy and Greece. New mutations were detected at the following positions: C-P80H and C-P80L in single isolates in Germany and France. The resistance factor of these mutations was very low. Depending on the regions, the overall frequency of mutation B-H272Y, /R and B-N230I remains at a moderate to high level in Chile and Germany, resp. The mutation B-P225H /L /F remains overall at a low level. In France, low levels of resistance were found.

Grape powdery mildew (*Erysiphe necator*)

(BASF, Bayer)

In 2017, the mutation B-H242R or strains with the B-H242R phenotype were detected at heterogenous levels in Hungary, Slovakia and Slovenia. Low levels were found in single samples in France and in Italy in only one sample from the South.

Full sensitivity was observed in Portugal, Germany, Spain and Greece.

The mutation C-G169D/S or its phenotype was not detected in 2017 studies.

Historical background:

Extensive monitoring programs were carried out since **2003**. All isolates tested were sensitive, within the baseline (Austria, France, Germany, Hungary, Portugal, Spain, Switzerland). Single strains carrying a mutation (SDH subunit C-G169D) with moderate resistance factors were detected in single fields in Italy (retrospective investigations from **2014** samples, no detection in **2015**), Slovenia and Greece (both from **2015** samples), resp.

In **2016**, the mutation B-H242R was detected in Czech Republic, Slovakia and in Hungary and at very low levels in France. The mutation C-G169D was not detected in 2016 studies. Full sensitivity was observed in Greece, Portugal, Germany, Italy, Spain and Austria.

1.3 Pomefruit and stonefruit diseases

Apple scab (*Venturia inaequalis*)

(Syngenta, DuPont, BASF, Bayer)

Samples analyzed so far showed full sensitivity, coming from Germany, Italy, Portugal, Spain, France, Belgium, the Netherlands, Hungary, Ukraine, the United Kingdom, Greece, Austria, Turkey and Poland.

All samples tested were fully sensitive.

Historical background:

Extensive monitoring programs were carried out since **2005**.

Data from commercial sites in **2015** show full sensitivity in Bulgaria, Belgium, Switzerland, Germany, Spain, France, Greece, Hungary, Croatia, Ireland, Italy, Latvia, Lithuania, Netherland, Romania, Portugal, Poland, the United Kingdom and Serbia. Single isolates from trial sites with

slightly reduced sensitivity were found in Bulgaria, Italy and Spain. Product performance was not affected. For resistant isolates originating from trial sites in Italy, the mutations B-T253I and C-H151R were detected.

In **2016**, analysed samples showed full sensitivity, coming from the United Kingdom, Germany, Italy, Portugal, Spain, France, Belgium, the Netherlands and Poland.

Apple powdery mildew (*Podosphaera leucotricha*)
(Bayer, Syngenta)

In 2017, all isolates tested showed full sensitivity. Samples originated from Belgium, Germany, Spain, France, Portugal, the Netherlands, Hungary, Italy, Croatia and Poland.

Historical background:

All isolates tested in **2014** were sensitive, within the baseline (France, Spain, Austria, Hungary, Germany, Romania, Bulgaria).

All isolates tested in **2015** coming from Belgium, Switzerland, Germany, Spain, France, Italy, Latvia, the Netherlands, Portugal and Poland were sensitive, within the baseline.

In **2016**, all isolates tested showed full sensitivity. Samples originated from Belgium, Bulgaria, Switzerland, Germany, Spain, France, Portugal, Greece, the Netherlands, Czech Republic, Hungary, Italy, Lithuania, Poland and Romania.

Brown rot on stonefruit (*Monilinia* spp.)
(Syngenta)

Samples were analyzed originating from Croatia, Czech Republic, France, Germany, Italy, Poland, Romania and Spain, including cherry, nectarines, peach and plum.

Reduced sensitivity was detected in samples coming from Germany, Spain, France, Croatia and Italy.

Full sensitivity was observed in Czech Republic, Poland and Romania.

Historical background:

Sensitivity of samples from Spain, France, Italy, Germany and Poland was analysed and showed full sensitivity in **2014**.

In **2015**, samples originating from Belgium, France and Hungary were all sensitive, within the baseline.

In **2015**, samples from Italy, France and Spain were studied (species not confirmed). Single isolates with reduced sensitivity were detected at 3 trial sites in France. Only sensitive phenotypes were reported from Italy and Spain.

In **2016**, samples from Italy, France, Poland, Hungary and Greece were studied (species: *M.laxa*, *M.fructicola*, *M.fructigena*). There is no indication for reduced sensitivity and mutations in the *sdh* genes.

1.4. Cucurbit diseases

Cucurbit powdery mildew (*Sphaerotheca fuliginea*, syn. *Podosphaera xanthii*, *Erysiphe cichoracearum*, *Golovinomyces cichoracearum*)
(Syngenta, BASF, Bayer)

P.xanthii samples in 2017 were analysed originating from zucchini, cucumber and melon.

Single samples showed resistance and were found in Belgium, Italy, Poland, Germany, France, Spain and Greece. No resistance was detected in Portugal.

All samples originating from melon were fully sensitive.
Decreased sensitivity was reported in a few samples from China.

Historical background:

Extensive monitoring programs were carried out since **2005**.

Monitoring studies in **2014** were carried out in France, Italy, Greece, Germany, Switzerland, China and Spain. Full sensitivity was observed except for Spain, Italy and China, where single resistant isolates were detected.

In **2015**, full sensitivity was observed in Belgium, Bulgaria, Spain and the Netherlands. Resistant isolates were detected in Germany, Czech Republic, Italy, Poland, Greece and France.

P.xanthii samples in **2016** were analysed originating from zucchini, cucumber, melon and water melon. Single samples showed resistance and were found in Belgium, France and Greece. Decreased sensitivity was reported in a few samples from China. No resistance was detected in Spain, Italy, the Netherlands.

1.5 Other crops

Strawberries and soft fruit – Grey mold (*Botrytis cinerea*) (Bayer, DuPont)

In 2017, the majority of isolates showed full sensitivity, originating from France.

Low levels found in Germany, United Kingdom, Sweden, Poland and Denmark.

In all countries mentioned, the mutations B-H272R and B-H272Y were detected at moderate levels and B-N230I as well as B-P225F were detected at low levels.

Historical background:

Extensive monitoring programs were carried out since **2003**.

In **2015**, monitoring was carried out in Germany, Belgium, Hungary, Italy, France, Denmark, Poland, Sweden, the Netherlands (raspberry) and the United Kingdom. Some resistant isolates were detected in Germany, Poland, Belgium and the United Kingdom.

When used according to manufacturers' recommendations, field performance of SDHI containing products is good.

In **2016**, the majority of isolates showed full sensitivity, originating from Germany, France and the United Kingdom. In all countries mentioned, the mutations B-H272R and B-H272Y were detected at moderate levels and B-N230I was detected at low levels.

Grey mold (*Botrytis cinerea*) on other vegetable crops (tomato, lettuce, zucchini, cucumber) (Du Pont)

No monitoring was carried out in 2015, 2016 and 2017.

Historical background:

Monitoring data were reported from **2013** (France, Italy, Portugal, Greece).

Resistant isolates were found in Italy, Greece and Portugal. No cases of reduced field performance were reported.

Vegetables – *Alternaria* spp. (cabbage, broccoli, carrot) (Syngenta)

Samples were analysed originating from Croatia, France, Lithuania, Denmark, Germany, Italy, Netherlands, Poland, Portugal, Spain, Sweden and Bulgaria, coming from broccoli, cabbage and carrots.

Fully sensitivity was observed in *A.brassica*, *A.brassicicola* and *A.dauci*.

Reduced sensitivity was observed in *A.alternata* samples originating from Croatia, Germany, Netherlands and Poland coming from carrots and cabbage.

Historical background:

Resistance was detected in **2014** at low frequency in *A. brassicae* and *A. brassicicola* isolated from cabbage in Germany and *A. alternata* sampled from broccoli in Spain.

In **2015**, a single isolate with resistance was detected in *A.alternata* from broccoli in Spain.

No data were reported for **2016**.

Peas, beans – White mold (*Sclerotinia sclerotiorum*)
(BASF)

In 2017, full sensitivity was observed in samples originating from France, Germany and Poland.

In 2015, samples from the Netherlands and Belgium were all sensitive, within the baseline.

No monitoring was carried out in **2016**.

Oilseed rape – White mold (*Sclerotinia sclerotiorum*)
(BASF, Bayer, Syngenta, Isagro/ FMC)

Disease pressure in 2017 was low to moderate.

In the season 2017, samples were tested from Germany, France, the United Kingdom, Czech Republic, Latvia, Sweden, Romania, Denmark and Poland.

Full sensitivity was observed in Czech Republic, Romania and Poland.

Low frequency of resistance was detected in Germany, France, the United Kingdom, Latvia, Sweden and Denmark.

Historical background:

Extensive monitoring programs were carried out since **2006**.

In **2014** and **2015**, single resistant isolates were detected in France. No resistant isolates were detected in 2014 in Czech Republic, Germany, the United Kingdom and Poland.

In 2015, no resistance was detected in the Netherlands, Belgium, France, Poland, Czech Republic, Croatia and Germany.

In the season **2016**, samples were tested from Germany, France, the United Kingdom, Czech Republic, Lithuania, Denmark and Poland. No to low frequency of resistance was detected in France and Germany.

For information on previously detected mutations please refer to “[link to mutation table](#)”.

Oilseed rape - Blackleg (*Leptosphaeria maculans*, *L.biglobosa*)
(BASF, DuPont, Bayer)

Monitoring data for 2017 will be presented at the next working group meeting in December 2018.

Historical background:

All isolates tested were sensitive, within the baseline (France, Germany, Poland, United Kingdom and Hungary).

2016 samples coming from France and Germany were all sensitive, within the baseline.

Potato – Early blight, Alternaria leaf spot (*Alternaria solani*, *A.alternata*)
(Syngenta, BASF, Bayer)

In *A.alternata*, no resistance was detected in Hungary in 2017. Low frequency of resistance was detected in Czech Republic, Germany, Romania and Poland.

In *A.solani*, no resistance was detected in Poland, Spain, Hungary and Romania. Low frequency of resistant isolates was detected in Czech Republic and France. Moderate frequency was detected in Denmark, Belgium, Germany, the Netherlands and Sweden.

Historical background:

Monitoring studies are carried out since **2009**.

In **2015**, no SDHI resistance was detected in *A.solani* in Austria, France, Greece, Hungary, Italy, Slovakia and Spain. Isolates with reduced sensitivity were detected in Europe in Belgium, Germany, the Netherlands and Denmark. In *A.alternata*, isolates with reduced sensitivity were detected in Austria, Belgium, Germany, Hungary, Italy, Slovakia and the Netherlands. Full sensitivity was found in Finland, France, Greece, Latvia and Spain.

The practical relevance of these mutations and the role of *A.alternata* in the disease complex are still under discussion by the research community.

In *A.alternata*, no resistance was detected in Bulgaria, Romania, Sweden, France, the United Kingdom and Slovakia in **2016**. Low frequency of resistance was detected in Hungary and Poland. Low to moderate frequency of resistance was detected in Switzerland and Germany, and moderate levels in Belgium. In *A.solani*, no resistance was detected in Czech Republic, Spain, Finland, Greece, Hungary and Slovakia. Low frequency of resistant isolates was detected in Poland, Denmark, Italy, Romania and the United Kingdom. Moderate frequency was detected in Belgium, Germany, the Netherlands and Sweden.

For information on previously detected mutations please refer to "[link](#) to mutation table".

Potato – Silver scurf (*Helminthosporium solani*) (Syngenta)

Monitoring data from 2016 from Germany, France and the USA showed a low frequency of resistance.

Full sensitivity was reported from the United Kingdom.

Historical background:

In **2014**, single resistant isolates were detected in Belgium and the Netherlands. No resistant isolates were detected in the United Kingdom, France and Germany.

Potato – Stem canker/ Black scurf (*Rhizoctonia solani*) (Syngenta)

In 2016, samples from Germany, France, The United Kingdom and Netherlands showed full sensitivity.

Historical background:

All samples analysed from the United Kingdom, the Netherlands, France and Germany in **2014** showed full sensitivity.

Tomato – Early blight, Alternaria leaf spot (*Alternaria solani*, *A.alternata*) (Syngenta)

In 2017, full sensitivity was found for *A.alternata* in Spain, Hungary and Romania. Low frequency of resistance was observed in Italy.

For *A.solani*, full sensitivity was found in Italy, Poland and Slovakia.

Historical background:

In **2015**, no SDHI resistance was detected in *A.solani* in Poland, Bulgaria and Spain. In *A.alternata*, a single isolate from Italy showed reduced sensitivity. No SDHI resistance was reported from Spain and Bulgaria.

In *A.solani*, no resistance was detected in Poland and Italy in **2016**. In *A.alternata*, few isolates showing reduced sensitivity were detected in Poland, Italy and Greece.

For information on previously detected mutations please refer to "[link](#) to mutation table".

Tomato – Powdery mildew (*Oidium neolycopersici*)

(Syngenta)

All 2016 samples originating from Belgium, Spain, France and the Netherlands showed full sensitivity.

Almonds – Leaf spot (*Alternaria alternata*)

(Syngenta)

In samples originating from 2015 and 2016, resistance was confirmed in California/ USA.

Soybean – Asian soybean rust (*Phakopsora pachyrhizi*)

(Syngenta, Bayer, BASF, DuPont)

Soybean rust samples have been tested for sensitivity to SDHI fungicides since 2007.

In general, disease pressure in the season 2017/18 was moderate.

Field efficacy of SDHI-containing fungicides remains generally good. Substantial monitoring programs have been carried out and are still ongoing.

SDHI-sensitivity in monitoring programs from the season 2017/18 was comparable to the previous season and no further spread of the resistant mutation I86F was observed.

In some areas, even a reduction in the frequency of less sensitive populations was observed. If these findings are related to improved resistance management practices needs to be further clarified.

Historical background:

In 2016/17, in many hundreds of trials as well as in commercial fields analyzed throughout Brazil the performance of SDHI-containing fungicides was as expected based on experience from previous years.

For the first time in the season 2015/16 and more frequently in 2016/17 at sites with a history of intensive SDHI-use and very high disease pressure, cases of reduced performance have been detected.

Further analyses of populations from 2016/17 have shown reduced sensitivity to varying degrees.

No to high frequencies of less sensitive populations were observed in the South of Brazil (Rio Grande do Sul, Parana, Mato Grosso do Sul).

A low proportion of less sensitive populations was found in Goias, Minas Gerais, Sao Paulo and Mato Grosso.

No to very low frequency of less sensitive populations was found in Bahia, Maranhao and Tocantins.

Currently, the resistance mechanisms are not fully understood. The initial characterization of populations collected in 2015/16 indicated a mutation in the C-subunit at position I86F. The relevance and distribution of this mutation for the reduced SDHI sensitivity partly observed as well in 2016/17 samples is still under investigation. Intensive monitoring programs are running to investigate the magnitude and relevance of the findings.

Samples from the season 2016/17 from Bolivia were sensitive, whereas the target site mutation was detected in samples from Paraguay. Analysis on volunteer soybeans also showed the presence of the target mutation in Paraguay and Brasil, but not in Bolivia.

Species can carry different mutations which affect SDHIs. A few mutations can lead to different sensitivities depending on the chemical structure of the active ingredient. As all SDHIs are cross-resistant, resistance management must be the same for all SDHIs. All monitoring and guideline related statements refer to the entire group of SDHIs.

Soybean – Target spot (*Corynespora cassiicola*)

Monitoring programs have been carried out for the season 2016/17 and 2017/18. Preliminary results showed the presence of single isolates with reduced sensitivity. Further molecular analysis is needed to confirm the sensitivity phenotypes.

All samples analyzed from Brasil in 2014/15 showed full sensitivity.

Banana – Black sigatoka (*Mycosphaerella fijiensis*) (Syngenta, Bayer, BASF)

In vitro monitoring studies have revealed first isolates with reduced sensitivity in Ecuador and Costa Rica. No information on target site mutations is available at this point in time. Field performance was not affected. More details are published by the Banana FRAC working group ([Link](#)).

2. Detection of Resistance (other monitoring data sources, non-FRAC)

A complete overview on resistant plant pathogenic organisms, including published cases of SDHI resistance, can be viewed in the publications area of the FRAC website. See the [List of Resistant Plant Pathogens](#).

See following table for detected mutations: ([link](#)).

3. Use Recommendations

3.1 General SDHI Guidelines (all crops)

- Strategies and General Guidelines for the 2018 season
 - Strategies for the management of SDHI 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 designed in order to be proactive and to prevent or delay the development of resistance to SDHI fungicides.
 - A fundamental principle that must be adhered to when applying resistance management strategies for SDHI fungicides is that:

The SDHI fungicides (benodanil, benzovindiflupyr, bixafen, boscalid, carboxin, fenfuram, fluindapyr, fluopyram, flutolanil, fluxapyroxad, furametpyr, inpyrfluxam, isofetamid, isopyrazam, mepronil, oxycarboxin, penflufen, penthiopyrad, pydiflumetofen (=adepidyn), sedaxane, thifluzamide) are in the same cross-resistance group.

- Fungicide programs must deliver effective disease management. Apply SDHI 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 SDHI fungicide based products within a total disease management program must be limited.
- When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action
- Mixtures of two or more SDHI fungicides can be applied to provide good biological efficacy; however, they do not provide an anti-resistance strategy and must be treated as a solo SDHI for resistance management. Each application of such a mixture when used in a spray program counts as one SDHI application.
- SDHI fungicides should be used preventively or at the early stages of disease development.
- Please refer to the "mixture document" ([link](#)) for more information on fungicide mixtures for resistance management.
- Species can carry different mutations which affect SDHIs. A few mutations can lead to different sensitivities depending on the chemical structure of the active ingredient.
- As SDHIs are cross-resistant, resistance management must be the same for all SDHIs.
- All monitoring and guideline related statements refer to the entire group of SDHIs.

3.2 SDHI Guidelines – Grapes

- Apply SDHI fungicides according to manufacturers' recommendations.
- When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner:

- should provide satisfactory disease control when used alone on the target disease
- must have a different mode of action
- Apply a max. of 3 SDHI-containing fungicides per year over all diseases, solo or in mixture with effective mixture partners from different cross-resistance groups but not more than 50% of the total number of applications.
- A maximum of 4 SDHI fungicide applications may be used where 12 or more fungicide applications are made per crop.
- If used solo, apply SDHI fungicides in strict alternation with fungicides from a different cross-resistance group.
- If used in mixture, apply SDHI fungicides in a maximum of 2 consecutive applications.
- Apply SDHI fungicides preventively.
- For SDHI fungicide applications specifically targeted against grey mold, *Botrytis cinerea*, refer to the table below.

Grey mold (*Botrytis cinerea*) spray table:

Total number of <i>Botrytis cinerea</i> spray applications per crop	1	2	3	4	5	6	>6
Maximum recommended Solo SDHI fungicide sprays (apply in strict alternation)	1	1	1	2	2	2	3
Max. recommended SDHI fungicide sprays in mixture (apply a max. of 2 consecutive applications)	1	1	2	2	2	3	3

3.3 SDHI Guidelines – Pomefruit

- Apply SDHI fungicides according to manufacturers' recommendations.
- When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action
- Apply SDHI fungicides using not more than 2 consecutive applications.
- Apply SDHI fungicides preventively.

The following spray table shall be used as a guideline irrespective of the targeted disease in pomefruits.

Total number of spray applications per crop	1	2	3	4	5	6	7	8	9	10	11	12	>12
Maximum recommended Solo SDHI fungicide sprays	1	1	1	1	2	2	2	2	2	3	3	3	3
Max. recommended SDHI fungicide sprays in mixture	1	1	2	2	2	3	3	3	3	3	3	4	4

3.4 SDHI Guidelines – Stone fruits

- Apply SDHI fungicides according to manufacturers' recommendations.
- When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action
- Apply a max. of 3 SDHI-containing fungicides per year over all diseases, solo or in mixture with effective mixture partners.
- If used solo, apply SDHI fungicides in strict alternation with fungicides from a different cross-resistance group.
- If used in mixture, apply SDHI fungicides in a maximum of 2 consecutive applications.
- Apply SDHI fungicides preventively.

3.5 SDHI Guidelines – Other multi-spray crops (e.g. vegetables, including small berries and strawberries)

- When mixtures are used for SDHI fungicide resistance management, applied as tank mix or as a co-formulated mixture, the mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action

The following spray table shall be used as a guideline irrespective of the targeted disease in the crops specified above.

Total number of spray applications per crop	1	2	3	4	5	6	7	8	9	10	11	12	>12
Maximum recommended Solo SDHI fungicide sprays (apply in strict alternation)	1	1	1	1	2	2	2	3	3	3	3	4	*
Max. recommended SDHI fungicide sprays in mixture (apply a max. of 2 consecutive applications)	1	1	1	2	2	3	3	3	3	3	4	4	*

* When more than 12 fungicide applications are made, observe the following guidelines:

- When using a SDHI fungicide as a solo product, the number of applications should be no more than 1/3 (33%) of the total number of fungicide applications per season.
- For programs in which tank mixes or pre-mixes of SDHI are utilized, the number of SDHI containing applications should be no more than 1/2 (50%) of the total number of fungicide application per season.
- In programs where SDHIs are made with both solo products and mixtures, the number of SDHI containing applications should be no more than 1/2 (50%) of the total no. of fungicide applied per season.

- If used solo, apply SDHI fungicides in strict alternation with fungicides from a different cross-resistance group.
 - If used in mixture, apply SDHI fungicides in a maximum of 2 consecutive applications.
-

3.6 SDHI Guidelines - Banana

Guidelines for the use of SDHI fungicides in banana are published by the Banana FRAC working group ([link](#)) (next meeting scheduled for 2018).

3.7 SDHI Guidelines – Cereals

3.7.1. Foliar applications

- Apply SDHI fungicides always in mixtures
 - The mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action
 - Apply a maximum of 2 SDHI fungicide containing sprays per cereal crop.
- Apply the SDHI fungicide preventively or as early as possible in the disease cycle. Do not rely only on the curative potential of SDHI fungicides. Strongly reduced rate programs including multiple applications must not be used. Refer to manufacturers' recommendations for rates.

3.7.2. Seed treatment applications

SDHIs 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 SDHI fungicide is used as a seed treatment on cereals, there should be no implications regarding SDHI FRAC guidelines on the use of foliar SDHI fungicides on the same crop as long as the SDHI seed treatment is directed by rate and efficacy against seed and soil borne diseases or 'low risk' foliar pathogens (Link to [FRAC pathogen risk list](#)).

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

3.8 Soybeans

Species can carry different mutations which affect SDHIs. A few mutations can lead to different sensitivities depending on the chemical structure of the active ingredient. As all SDHIs are cross-resistant, resistance management must be the same for all SDHIs. All monitoring and guideline related statements refer to the entire group of SDHIs.

- Apply SDHI fungicides always in mixtures

- The mixture partner:
 - should provide satisfactory disease control when used alone on the target disease
 - must have a different mode of action
- Apply a maximum of 2 SDHI fungicide containing sprays per soybean crop (no soy after soy/ double cropping)
- Apply the SDHI fungicide preventively or as early as possible in the disease cycle. Do not rely only on the curative properties of SDHIs, or SDHI-containing mixtures
- Strongly reduced rate programs including multiple applications must not be used. Refer to manufacturers' recommendations for rates

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 partially resistant soybean varieties, reduce the planting window, give preference to early-cycle varieties and endorse the destruction of volunteers.

3.9 All other crops

- Refer to the general guideline for the use of SDHI fungicides.

Oilseed rape

Extensive monitoring programs have been carried out. Reduced sensitivity has been detected in *S.sclerotiorum*.

Further monitoring programs will continue and clarify the necessity for a specific crop guideline. The general guidelines for the use of SDHIs are currently considered to be sufficient because current data shows sporadic detection, no consistent increase and spread of resistant mutations. In addition, the life cycle of the pathogen, its distribution and rotation with non-host crops confirm that *Sclerotinia* in OSR justify the classification as a low risk pathogen (Link to [FRAC pathogen risk list](#)).

3.10 Seed treatment for other crops

There are no guidelines for additional crops because currently the relevant pathogens are not considered as high-risk pathogens. Monitoring programs will continue to be carried out and serve as basis for regular reviews of the need for specific guidelines.