Succinate Dehydrogenase Inhibitor (SDHI) Working Group

Meeting on January 21 and June 17, 2020 and September 23rd, 2020
Protocol of the discussions and use recommendations of the SDHI Working Group of the Fungicide Resistance Action Committee (FRAC)

Participants

BASF	Kristin Klappach (Chairwoman)
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	Rosie Bryson (not in September)
	Martin Semar (not in September)
Bayer	Andreas Mehl
	Dominique Steiger (not in September)
	Juergen Derpmann
Corteva	Jean-Luc Genet (not in September)
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Venue:
January 21: Lindner Hotel & Conference Centre, Frankfurt/ Main, GermanyWebex
June 17: Virtual Webex-Meeting
September 23rd: Virtual Webex-Meeting

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1. Monitoring Results 2019 (FRAC members)

Wheat – Septoria leaf blotch (*Mycosphaerella graminicola*)
(Bayer, Syngenta, BASF, Isagro/ FMC, Sumitomo, Adama)

Disease pressure in 2019 was moderate but regionally variable. Field performance of SDHI-fungicides against Septoria was good.
In 2019, the majority of isolates was sensitive and the overall situation stable compared to 2018, as was the frequency for the isolates showing low resistance factors. C-T79N and C-N86S were the most frequent mutations in this group in the last years.
All isolates from Austria, Bulgaria, Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Lithuania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Romania, Russia and Ukraine were sensitive.
A mostly sensitive situation was monitored in France with a low frequency of isolates with low resistance factors at few sites.
As in previous years, isolates bearing the mutation C-H152R continued to be detected at overall low frequencies in 2019 in Germany, Ireland, the Netherlands and the United Kingdom.
Single strains carrying double mutations associated with C-N86S and C-T79N were reported for the first time. The impact on sensitivity ranges from low to high depending on the combination. The fitness of these isolates and impact on product performance is still under investigation.

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.
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.
Disease pressure in **2018** was low but regionally variable. Field performance of SDHI fungicides against Septoria was good.
In **2018**, sensitivity data for more than 2.000 isolates were presented from a broad range of countries. The majority of isolates was sensitive. Compared to **2017**, the frequency of isolates showing low resistance factors increased in Northern-Germany, Ireland, the Netherlands and the United Kingdom. These isolates were detected again at low frequency in Denmark, France, Southern-Germany, Poland and for the first time in Ukraine. These isolates are mainly associated to the following mutations: B-T268I/A, B-N225I, B-R265P, C-A84F, C-P127A, C-T168R, C-T79N/I, C-R151S/T/M, C-N86S/A, C-W80S, C-V166M, D-I50F, D-M114V, D-D129G. Among the mentioned mutations, the C-T79N and C-N86S were the most frequent mutations in the last years.
All isolates from Austria, Bulgaria, Czech Republic, Hungary, Italy, Latvia, Lithuania, Slovakia, Spain, Sweden, Switzerland, Romania and Russia were sensitive.
Single isolates with moderate resistance factors and bearing the mutation H152R (SDH subunit C) were also detected in **2018** in Germany, Ireland, the Netherlands and the United Kingdom. For the first time, this mutation was detected in low frequency in a single population originating from France (Normandie). The overall frequency of this mutation in Europe remains at a low level.
The following mutations were also reported but are not associated with any sensitivity change: B-C266G, C-N33T, C-N34T, C-L184W.
For full details on historical monitoring data, please refer to the archive on the SDHI FRAC WG webpage.

Wheat – Brown rust (*Puccinia recondita*)
(Syngenta, Sumitomo)

Extensive monitoring programs were carried out since 2005.
In 2019, samples were analysed from Belgium, Czech Republic, France, Germany, Italy, Poland, Slovakia and the United Kingdom and showed full sensitivity.

Historic background:
Samples from the following countries were tested in **2018**: Belgium, Denmark, France, Germany, Hungary, Sweden and the United Kingdom. All tested isolates were sensitive, within the baseline.
One single isolate, showing a low resistance factor (~5) has been identified in Pas de Calais, France and was genetically characterized without any detection of a mutation in sdh subunits B, C and D.

Wheat – Yellow rust (*Puccinia striiformis*)
(Bayer)

In 2019, samples from Belgium, Denmark, Germany, Latvia, Sweden and the United Kingdom were tested and showed full sensitivity, within the baseline.

Wheat – Snow mold (*Microdochium* spp.)
(Syngenta)

Disease pressure in 2019 was moderate. Isolates from Belgium, Germany, Hungary, the Netherlands, Ukraine and the United Kingdom were fully sensitive. Single resistant isolates bearing the mutation B-H253Q were detected in Italy and characterized as *M.nivale* var. *majus*. However, SDHI-containing products were still effective.

Historical background:
Monitoring programs carried out in **2015** showed full sensitivity of isolates from Germany, France, Italy, Slovakia and the United Kingdom, confirming the results from **2014**.
Data from **2016** and **2017** from Belgium, Germany, Denmark, Finland, France, Italy, Lithuania, Latvia, Poland, Russia, Sweden, Ukraine and the United Kingdom showed a fully sensitive situation.
Disease pressure in **2018** was very low. Isolates from France, Hungary, Italy, Poland and Spain were fully sensitive.

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

In 2019, full sensitivity was found in Czech Republic, Poland and the United Kingdom.

Historical background:
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.
In **2018**, full sensitivity was found in Belgium, Denmark, France, Germany and the United Kingdom.

Wheat – Tan spot (*Pyrenophora tritici-repentis*)
(Syngenta)

2019 samples from Finland, Latvia and the United Kingdom showed full sensitivity.

Wheat – Sharp eye spot (*Rhizoctonia* spp.)
(Syngenta)

2019 samples from Germany and the United Kingdom were fully sensitive.

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

Disease pressure was generally moderate in 2019.

In 2019, the frequency of mutations was similar to the previous season.
The frequency of insensitive isolates was low in Bulgaria, Czech Republic, Denmark, Greece, Hungary, Italy, Poland, Spain, Sweden, Switzerland and Ukraine. Moderate to

high frequencies were observed in Austria, Belgium, France, Germany, Ireland, the Netherlands and the United Kingdom. Among the mutations with moderately decreased sensitivity, C-G79R, C-H134R and C-S135R are the most frequently detected mutations. No mutations or reduced sensitivity were detected in Hungary, Latvia, Lithuania, Romania, Russia and Slovakia.
Monitoring is ongoing.

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 Germany, France, Italy 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 Czech Republic, Denmark, Italy, Poland, Southern France, Southern Germany and the United Kingdom. Moderate frequencies were observed in Northern Germany and Northern France. Among the mutations with moderately decreased sensitivity, C-G79R 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 Bulgaria, Estonia, Finland, Hungary, Ireland, Latvia, Lithuania, Romania, Russia, Slovakia, Spain, Sweden and the Ukraine (in **2016**).
For full details on historical monitoring data, please refer to the archive on the SDHI FRAC WG webpage.
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 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, Denmark, Greece (trial site), Italy, Lithuania, Poland, Sweden and the Ukraine. Moderate frequencies were observed in Germany and the United Kingdom 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 the 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 Bulgaria, Estonia, Finland, Hungary, Ireland, Latvia, Romania, Russia, Slovakia and Spain.
Disease pressure was generally low in **2018**. Thus, the field performance of SDHI-containing fungicides against net blotch is hard to evaluate.
In **2018**, the frequency of mutations was comparable to the previous season.
The frequency of insensitive isolates was low in the Czech Republic, Denmark, Hungary, Italy, Poland, Sweden and Ukraine. Moderate to high frequencies were observed in Belgium, France, Germany, Ireland, the Netherlands and the United Kingdom. Among the mutations with moderately decreased sensitivity, C-G79R, C-H134R and C-S135R are the most frequently detected mutations.

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

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

Disease pressure was low in 2019. Monitoring programs were carried out since 2003.

In 2019, isolates coming from Belgium, France, Germany, Ireland, Poland and the United Kingdom showed full sensitivity.

Historical background:
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.
In **2018**, isolates coming from Denmark, France, Germany, Ireland, Poland and the United Kingdom showed full sensitivity.

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

Disease pressure was low to moderate in 2019.
Preliminary data show no mutations in Austria, Italy, Latvia, Norway, Spain, Slovenia, Slovakia and Switzerland.
Low frequency has been found in Austria, Hungary, Poland, Sweden and Ukraine.
A heterogeneous situation, ranging from low to high (frequency of mutations and sensitivity), was observed in Belgium, Germany and the Netherlands.
Moderate to high frequencies of mutations were detected in Denmark, France, Ireland and the United Kingdom.
Significantly decreased sensitivity is mainly associated with the mutations C-G91R, C-H146R/L, C-G171D or C-H153R. Additionally, mutations linked to lower resistance factors (C-N87S, B-T267I, B-N224T) were detected.

Historical background:
In **2014**, single isolates with slightly decreased sensitivity were detected in 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 United Kingdom with high proportions of SDHIs in spray programs. Samples taken from the untreated plots at the same sites showed baseline level sensitivity.

In **2017** (disease pressure moderate), reported data show no mutations in Finland, Norway, Spain and Greece. Low frequency had 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.
Disease pressure was low in **2018**.
No mutations were found in Czech Republic, Finland, Italy, Latvia, Norway, Romania, Russia, Spain, Sweden and Switzerland.
Low frequency has been found in Austria, France, Hungary, Poland and the Ukraine.
A heterogeneous situation, ranging from low to high (frequency of mutations and sensitivity), was observed in Belgium, Germany, Denmark, the United Kingdom, Ireland and the 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.

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

Monitoring programs were carried out since 2006. All isolates tested until 2014 were sensitive, within the baseline.
2019 samples from France and the United Kingdom showed a similar sensitivity pattern as observed in 2018 with some isolates showing low resistance factors (no impact on field efficacy reported).

Historical background:
No monitoring was carried out in 2015, 2016 and 2017.
In **2018**, few isolates with a low resistance factor have been identified for the first time in France and the United Kingdom.
All isolates originating from Denmark, Germany and Sweden were fully sensitive.

Barley – smut (*Ustilago* spp.)
(Syngenta)

A monitoring program was carried out in 2019 including samples from Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Italy, the Netherlands, Poland, Romania, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. All isolates showed full sensitivity.

Historical background:
Samples collected in **2018** from the Czech Republic, Denmark, Ireland, Italy, Poland, Sweden and the United Kingdom were fully sensitive.

Barley – Powdery mildew (*Blumeria graminis*)
(Sumitomo)

2019 monitoring programs included samples from Czech Republic, France, Germany and the United Kingdom and showed full sensitivity.

1.2. Grape diseases

Grape grey mold (*Botrytis cinerea*)

(Bayer)

Analysis of 2019 monitoring samples is ongoing.

Historical background:
Extensive monitoring programs were carried out since 2003.
In **2012**, few isolates with resistance to SDHIs 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.
In **2017**, 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.
In **2018**, monitoring in Germany and Italy resulted in overall low frequencies of the C-P225F mutations. C-N230I, C-P80H mutations were found to be increased to moderate levels in Germany. Compared to **2016**, the sensitivity of samples from Chile decreased slightly.

Grape powdery mildew (*Erysiphe necator*)

(BASF, Bayer)

Monitoring is ongoing.
Bioassays carried out in 2019 showed full sensitivity in Austria, Croatia, Germany, Italy, Portugal, Slovenia and Spain.
Mutation analyses showed the mutation B-H242R at low levels in France, Turkey and Ukraine.
The mutation C-G169D was detected in 2019 in Turkey in single commercial sites.
The mutation B-I244V was detected in a single sample originating from Ukraine.

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.
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.
In **2018**, the mutation B-H242R was detected at heterogenous levels in Hungary and Greece.
The mutation C-G169D was detected in **2018** in Ukraine in single commercial sites.
Full sensitivity was observed in Croatia, France, Germany, Italy, Portugal and Spain.

1.3 Pomefruit and stonefruit diseases

Apple scab (*Venturia inaequalis*)
(Corteva, BASF, Bayer)

Samples analyzed from 2019 so far showed full sensitivity, coming from Austria, Belgium, France, Germany, Hungary, Italy, Romania, Spain, Poland, Portugal and the United Kingdom.

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**, analyzed samples showed full sensitivity, coming from the United Kingdom, Germany, Italy, Portugal, Spain, France, Belgium, the Netherlands and Poland.
Samples analyzed in **2017** showed full sensitivity, coming from Germany, Italy, Portugal, Spain, France, Belgium, the Netherlands, Hungary, Ukraine, the United Kingdom, Greece, Austria, Turkey and Poland.
Samples analyzed in **2018** showed full sensitivity, coming from Austria, Belgium, France, Germany, Greece, Hungary, Italy, Poland, Portugal, Romania, Spain, Turkey and the United Kingdom. All samples tested were fully sensitive.

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

2019 monitoring programs are ongoing.

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.
In **2017**, all isolates tested showed full sensitivity. Samples originated from Belgium, Germany, Spain, France, Portugal, the Netherlands, Hungary, Italy, Croatia and Poland.
In **2018**, all isolates tested showed full sensitivity. Samples originated from Germany, Spain, France, Portugal, Hungary, Italy, Greece and Poland.

Brown spot on pear (*Stemphylium vesicarium*)
(Syngenta)

2019 monitoring program is ongoing. Samples analysed so far from a multi-year trial site in Portugal showed the presence of resistance.
In **2018**, samples were collected in Belgium, Italy, Portugal and Spain. Moderate frequency of resistance was found in Italy. Low frequency was detected in Belgium and Portugal. No resistance was detected in Spain.

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

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*.
Samples were analyzed originating from France, Germany, Greece, Hungary, Italy, Poland and Spain including cherry, apricots, nectarines, peach and plum.
Increased EC50 values were detected in single isolates. Further characterization of these isolates is ongoing.

Historical background:
Sensitivity of samples from Spain, France, Italy, Germany and Poland was analyzed 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.
Samples in **2017** 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 the Czech Republic, Poland and Romania.
The analysis of *Monilinia* species present in monitoring samples from **2017** and **2018** highlighted/ showed a higher frequency of *M. fructicola* and *M. laxa* compared to *M. fructigena*.
Samples were analyzed originating from Belgium, Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Italy, Poland, Romania and Spain, including cherry, apricots, nectarines, peach and plum.
Reduced sensitivity was detected at low frequency in samples coming mainly from trial sites in the Czech Republic, Germany, Greece, Romania, Spain, France and Italy.
Full sensitivity was observed in Belgium, Bulgaria, Croatia, Hungary and Poland.

1.4. Cucurbit diseases

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

P.xanthii samples in 2019 were analyzed originating from zucchini, cucumber and melon. Samples showing resistance were found in Italy, Turkey and Spain. No resistance was detected in France and Greece.

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 analyzed 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.
P.xanthii samples in **2017** were analyzed 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.
P.xanthii samples in **2018** were analyzed originating from zucchini, cucumber and melon. Single samples showed resistance and were found in Italy, Poland, Germany, Turkey and France. No resistance was detected Spain and Portugal.
In **2018**, samples were collected in 7 provinces in China. Decreased sensitivity was reported from samples at low frequency coming from 2 provinces (Hebei, Liaoning).

1.5 Other crops

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

In **2018**, isolates from France showed full sensitivity.
Low levels of mutants were found in Poland and Sweden. Moderate levels were detected in Denmark, Germany, Norway and the United Kingdom.
In **2019**, low levels of mutants were identified in Denmark, France and Germany. Moderate levels were observed in Poland and the United Kingdom.
In all countries mentioned, the mutations B-H272R and B-H272Y were detected at moderate levels and B-P225F was detected at low levels.
The frequencies of B-N230I and C-P80H were observed to increase slightly between **2018** and **2019**.

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.
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.

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

No monitoring was carried out in 2015, 2016, 2017, 2018 and 2019.

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)

No monitoring was carried out in 2019.

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**.
In **2017**, 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.
No monitoring was carried out in **2018**.

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

No monitoring was carried out in 2018 and 2019.

Historical background:
In **2015**, samples from the Netherlands and Belgium were all sensitive, within the baseline.
No monitoring was carried out in **2016**.
In **2017**, full sensitivity was observed in samples originating from France, Germany and Poland.

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

Disease pressure in 2019 was low.
In the season 2019, samples were tested from Czech Republic, France, Germany, Hungary, Romania, Slovakia, Poland, Ukraine and the United Kingdom. All samples showed full sensitivity.
Monitoring is ongoing.

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.
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.
In the season **2018**, samples were tested from France, Germany, Hungary, Romania, Poland and the United Kingdom.
A low frequency of adapted isolates was detected in France. The following mutations were associated to decreased sensitivity in past monitoring programs: B-H273Y, C-H146R, C-G91R, D-H132R, C-G150R, D-T108K.

For information on previously detected mutations please refer to “**link** to mutation table”.

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

2019 monitoring programs are still ongoing.

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.
All isolates analyzed from **2017/18** tested were sensitive, within the baseline (France, Germany, Poland and United Kingdom).

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

In *A.alternata*, no resistance was detected in Denmark and Latvia in 2019. Low frequency of resistance was detected in Germany, Hungary, Italy and Switzerland.
In *A.solani*, no resistance was detected in 2019 in Croatia, Czech Republic, Greece, Ireland, Norway and Poland. Low frequency of resistant isolates was detected in France. Moderate frequency was detected in Austria, Belgium, Germany, Hungary, the Netherlands and the United Kingdom.
Moderate to high frequencies were detected in Denmark and Sweden.
The following mutations have been detected: B-H278R/Y, C-H134R/Q, D-H133R with B-H278Y and C-H134R being the predominant mutations found.
In 2019 monitoring programs, the following new mutation was identified in one single isolate: D-D123E.

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.
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 **2017** 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.
The following mutations have been detected: B-H278R/Y, C-H134R, D-H133R with B-H278Y and C-H134R being the predominant mutations found.

For information on previously detected mutations please refer to "**link** to mutation table".

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

Samples in 2019 were analyzed coming from mainly commercial fields in Bulgaria, France, Germany, Hungary, Italy, the Netherlands and the United Kingdom.
Single resistant isolates were detected in France, Germany and the Netherlands. Considering long-term monitoring, the frequency of resistance is stable in the mentioned countries.

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.
Monitoring data from **2016** from Germany, France and the USA showed a low frequency of resistance. Full sensitivity was reported from the United Kingdom.

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

Samples were analyzed in 2018 originating from Germany, the Netherlands, Spain and the United Kingdom.
Full sensitivity was observed.

Historical background:
All samples analyzed from the United Kingdom, the Netherlands, France and Germany in **2014** showed full sensitivity.
In **2016**, samples from Germany, France, The United Kingdom and Netherlands showed full sensitivity.

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

For *A.alternata*, single resistant strains were detected in Italy, Poland and Portugal. Full sensitivity was found in Spain.
For *A. solani*, full sensitivity was found in Croatia, Italy and Spain.

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.
In **2017**, full sensitivity was found for *A. alternata* in Spain, Hungary and Romania. Low frequency of resistance was observed in Italy.
No monitoring data are available for **2018**.

For information on previously detected mutations please refer to "**link** to mutation table".

Tomato – Powdery mildew (Oidium neolycopersici)

No monitoring data are available for **2017, 2018** and **2019**.

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

Almonds – Leaf spot (*Alternaria alternata*)

No monitoring data are available for **2017, 2018** and **2019**.

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

Soybean – Asian soybean rust (*Phakopsora pachyrhizi*)

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

Soybean rust samples have been tested for sensitivity to SDHI fungicides since 2007 in Brasil and adjacent countries.
Disease onset was late and disease pressure in **2019/20** compared to last season was low to moderate.
Field efficacy of SDHI-containing fungicides remains generally good.
Substantial SDHI-sensitivity monitoring programs were running with samples from the season **2019/20**. These were based on detached leaf tests and the detection of mutations in the SDH genes. In most cases there was a good correlation between detached leaf assays and genetic evaluations. Genetic stuidies based on pyrosequencing, illumina sequencing, qPCR and whole SDH gene sequencing showed that the C-I86F mutation is currently the prevalent resistance meachnism and the main driver for observed sensitivity changes in the field. However also other mutations (C-N88S/D, C-H154R, C-G92R) have been identified at very low frequency from beginning of SDHI-adaptation in soybean rust. Their implication on SDHI sensitivity is currently not understood. Since such homologous mutations can be found and are relevant in other plant pathogens (e.g. *Zymoseptoria tritici* C-N86S, C-H152R; *Corynespora cassiicola* C-N75S ; *Pyrenophora teres* C-G79R), they will be further observed..

Results from Brazil : Majority of studies are finished. Analysed samples originated from both, commercial and trial sites (both treated and untreated plots) from the following states : Mato Grosso do Sul, Mato Grosso, Parana, Sao Paulo, Minas Gerais, Goias, Rio Grande do Sul, Santa Catarina and Tocantins.
In general, the sensitivity range was observed to be similar to the previous year and also the frequency of the C-I86F mutation was quite stable and comparable with the previous season

Results from Paraguay : Monitoring studies (sensitivity tests and mutation analysis) showed that the frequency fo SDHI adaptation is quite low and less frequent than in most Brazilian regions.

Results from Bolivia : Initial studies were performed and all samples analysed did not indicate any SDHI-adaptation. The tests were limited to sensitivity analysis by detached leaf assays.

Historical background:
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.
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.
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 shown the presence of the target mutation in Paraguay and Brasil, but not in Bolivia.
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. Samples originating from volunteer plants collected in Brasil during the soybean-free period in **2018** showed the presence of the mutation I86F at a comparable level to the previous monitoring programmes.
Disease pressure in **2018/19** was (compared to the last season) lower in the beginning and disease development was delayed. Disease pressure at the end of the growing season was high. 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 **2018/19** was variable compared to the previous season depending on sample timing, sampling location and seasonal factors.
The majority of samples contained the I86F mutation. However, the frequency of the mutation within the analysed samples was highly variable, ranging between 0 and very high as in the past. First evidence for fitness penalties in the I86F mutants were observed in monitoring studies by FRAC member companies and are further investigated. The relevance of these findings for SDHI field performance will be further investigated.

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*)
(BASF, Syngenta)

Monitoring programs have been carried out for the seasons 2018/19 and 2019/20. The studies for season 2019/20 are not fully completed, but the present data indicate an

increase in the frequency of isolates with reduced sensitivity in the last two seasons compared to the past.
Molecular analysis confirmed the presence of target site mutations B-H278Y and C-N75S in isolates with reduced sensitivity. These isolates were detected in Mato Grosso and Mato Grosso do Sul at moderate frequencies and at lower frequencies in other states (Parana, Sao Paulo, Tocantin, Goias, Minas Gerais, Rio Grande do Sul, Rodonia).

Historical background:
All samples analyzed from Brasil in **2014/15** showed full sensitivity.
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.
Status update, December **2018**:
Molecular analysis confirmed the presence of target site mutations B-H278Y and C-N75S in isolates with reduced sensitivity. These isolates were detected in Mato Grosso and at single sites in Rio Grande do Sul and Bolivia. All sites analyzed from Goias, Minas Gerais and Parana were sensitive.

Cotton – Ramularia leaf spot (*Ramularia areola*)
(BASF)

Studies from the season 2019/20 are running. Monitoring studies from 2018/19 showed full SDHI-sensitivity (Bahia, Goias, Mato Grosso, Mato Grosso do Sul).

Historical background:
Monitoring programs were carried out with samples originating from **2017/18** and **2018/19** coming from Mato Grosso, Goias, Bahia, Mato Grosso do Sul. All samples were fully sensitive.

Cotton – Target spot (*Corynespora cassiicola*)
(BASF)

Sensitivity tests and molecular analysis confirmed the presence of isolates with reduced sensitivity and these carried the target site mutation B-H278Y and C-N75S, as it has been found for *C. cassiicola* from soybeans. Such isolates were detected in Mato Grosso and Mato Grosso do Sul at moderate frequencies. In general, the frequency of SDHI adaptation in populations from cotton was lower than in populations from soybeans.

Banana – Black sigatoka (*Mycosphaerella fijijensis*)
(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. SDHI – Use Recommendations

3.1 SDHI – General SDHI Guidelines (all crops)

Strategies and General Guidelines for the 2020/21 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, isoflucypram, isopyrazam, mepronil, oxycarboxin, penflufen, penthiopyrad, pydiflumetofen, 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.

SDHI – Grey mold (*Botrytis cinerea*) spray table:

Total number of *Botrytis cinerea* 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 2020).

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 (see below for specifics on seed treatments).

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 foliar SDHI sprays.

3.8 SDHI-Guidelines – 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
  - The use of additional, non-cross-resistant modes of action should also be considered (ready-mixtures and tank-mixtures where legally possible)
- 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
- Respect the spray intervals according to the manufacturers' recommendations.

Good agricultural practices must be considered to reduce the 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 and harvest residues from previous crops such as cotton.

3.9 Cotton SDHI recommendation

Adhere to the general use guidelines for SDHI-fungicides.

- Apply SDHI always with a mixing-partner
  - The mixture partner:
  - Should provide acceptable disease control when used alone on the target disease
  - Must have a different mode of action (including multisites)
  - ready-mixtures and tank-mixtures can be considered as "mixtures" (where legally possible)
- Apply a maximum of 3 SDHI containing sprays per cotton crop, according to the table below.
- Apply SDHI fungicides in a maximum of 2 consecutive applications.

- Apply the SDHI fungicide preventively or as early as possible in the disease cycle.

Total number of spray application per crop	1	2	3	4	5	6	7	8	9	≥10
Max. recommended SDHI spray in mixture **(apply a max. of 2 consecutive applications)**	1	1	1	2	2	3	3	3	3	3

Good agricultural practices must be considered to reduce source of inoculum, disease pressure and resistance risk, e.g. no multiple cropping, give preference to disease-tolerant varieties and endorse the destruction of harvest residues from previous crops such as soybean.

3.10 SDHI-Guidelines – All other crops

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

SDHI – 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 SDHI-Guidelines – 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.