Succinate Dehydrogenase Inhibitor (SDHI) Working Group

7th Meeting on December 11, 2013
Protocol of the discussions and use recommendations of the SDHI Working Group of the Fungicide Resistance Action Committee (FRAC)

Participants

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1. Monitoring Results 2013 (FRAC members)

1.1 Cereal diseases

Wheat – Septoria leaf blotch (*Mycosphaerella graminicola*)
(Bayer CropScience, Syngenta, BASF, DuPont)

Disease pressure was high in most of the European countries in 2013. Field performance of SDHI fungicides against Septoria was good.

Extensive monitoring programs were carried out since 2003. All isolates tested in routine monitoring programs were sensitive, within the baseline. From 2012 samples, two isolates with reduced sensitivity were detected in France and UK (SDH subunit C: T79N, W80S). The resistance factors were low and field performance was not affected. In 2013, no such isolates were detected.

Wheat – brown rust (*Puccinia recondita*)
(BASF, Bayer CropScience, Syngenta)

Extensive monitoring programs were carried out since 2005. All isolates tested were sensitive, within the baseline.

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

Monitoring programs carried out in 2012 showed full sensitivity of isolates from different European countries.

Powdery mildew (*Blumeria graminis*)
(BASF)

Monitoring programs carried out in 2013 showed full sensitivity of isolates from different European countries.

Barley – net blotch (*Pyrenophora teres*)
(Bayer CropScience, Syngenta, Du Pont, BASF)

Disease pressure in 2013 was moderate in Europe. Field performance of SDHI fungicides against net blotch was good.

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 (H277Y). In 2013, more isolates were detected with reduced sensitivity. 5 mutations were detected (B-H277Y, C-G79R, C-H134R, C-S135R, C-N75S). The predominant mutation was C-G79R. The resistance factors were low for B-H277Y and moderate for C-G79R, C-H134R, C-S135R, C-N75S. However, field performance reductions were not reported. These findings emphasize the importance of adhering to FRAC guidelines.

Barley – scald (*Rhynchosporium secalis*)
(Bayer CropScience, Syngenta, BASF, DuPont)

Extensive monitoring programs were carried out since 2003. All isolates tested were sensitive, within the baseline.

Ramularia leaf spot (*Ramularia collo-cygni*)
(BASF, Bayer CropScience, Syngenta)

All isolates tested (2012) were sensitive, within the baseline.

Barley – rust (*Puccinia hordei*)
(Bayer CropScience)

All isolates tested were sensitive, within the baseline.

1.2. Grape diseases

Grape grey mold (*Botrytis cinerea*)
(Bayer CropScience, BASF)

Extensive monitoring programs were carried out since 2003.
Monitoring data were reported from 2012 and 2013.
Few isolates with resistance to SDHIs were detected in France and Germany in 2012 and in 2013 in addition to the mentioned countries in Italy. Isolates from Portugal were sensitive. No new mutations have been identified. For details on detected mutations see link at end of chapter.

Grape powdery mildew (*Erysiphe necator*)
(BASF, Bayer CropScience)

Extensive monitoring programs were carried out since 2003. All isolates tested were sensitive, within the baseline (Austria, France, Germany, Greece, Hungary, Italy, Portugal, Spain, Switzerland).

1.3 Pomefruit diseases

Apple scab (*Venturia inaequalis*)
(Syngenta, DuPont, BASF)

Extensive monitoring programs were carried out since 2005.
All isolates tested so far from commercial locations in 2012 and 2013 were sensitive, within the baseline (Austria, Belgium, France, Germany, Hungary, Italy, Latvia, Netherlands, Poland, Portugal, Spain, Switzerland, UK).
A small number of isolates with reduced sensitivity (moderate resistance factors) was detected at trial locations, one in Italy (carrying the C-H151R mutation) and one in Spain. However, product performance was not affected in these trials.

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

All isolates tested so far were sensitive, within the baseline (Bulgaria, Hungary, Poland, Spain).

1.4. Cucurbit diseases

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

Extensive monitoring programs were carried out since 2005.
Monitoring studies in 2013 were carried out in France, Italy, Switzerland and Spain.
Full sensitivity was observed except for Switzerland, where 1 resistant isolate was detected.

1.5 Other crops

Strawberries – grey mold (*Botrytis cinerea*)
(Bayer CropScience)

Extensive monitoring programs were carried out since 2003.
Monitoring was carried out in France, Germany, Italy, Portugal, Poland and UK.
In 2013, one isolate with reduced sensitivity was detected in Poland.

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

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

Monitoring data were reported from 2012 (France, Italy, Portugal, Greece).
Mutations at the target site were found in some isolates in Italy and Spain. No cases of reduced field performance were reported.

Eggplant – *Mycovellosiella nattrassi*
(Mitsui)

Monitoring was carried out in Japan. Resistance was reported from one prefecture (Detection and molecular characterization of Boscalid resistant Mycovellosiella nattrassii isolates from eggplant in Kochi Prefecture. Tomoyuki Okada, Kochi Agricultural Research Center. Gifu Uni. Japan March 30, 2013; 23rd Symposium of Research Committee on Fungicide Resistance).

Oilseed rape – Sclerotinia (*Sclerotinia sclerotiorum*)
(BASF, Bayer CropScience, Syngenta)

Extensive monitoring programs were carried out since 2006.
In 2012, no resistance was detected in Czech Republic, Germany, Latvia Poland and UK.
In 2013, monitoring programs were carried out in Czech Republic, UK, Latvia, Poland and Germany.
Single isolates with resistance were detected in Germany (B-H273Y) and France (D-H132R).
Field performance was not affected.

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

All isolates tested were sensitive, within the baseline (France, Germany, UK, Czech Republic, Poland).

Potato (*Alternaria solani, A.alternata*)
(Syngenta)

Monitoring studies are carried out since 2009.
No SDHI resistance was detected in *A.solani* in Belgium, France, Germany,. Isolates with reduced sensitivity were detected in Europe for the first time (Netherlands).
In *A.alternata*, mutations in the sdh genes were detected in Austria, Germany, France and Netherlands. The practical relevance of these mutations and the role of *A.alternata* in the disease complex is still under discussion. Field performance was not affected.

Soybean rust (*Phakopsora pachyrhizi*)
(Syngenta, Bayer CropScience)

Baseline sensitivity was established in 2010/11 to 2012/2013 in Brazil.
All samples remain sensitive, within the baseline.

Banana black sigatoka (*Mycosphaerella fijijensis*)
(Syngenta, Bayer CropScience, 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 in the "List of Resistant Plant Pathogens".

See following table for detected mutations: Published and newer cases of SDHI resistance in fungi.

3. Use Recommendations

3.1 General SDHI Guidelines (all crops)

- Strategies and General Guidelines for the 2014 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, fluopyram, flutolanil, fluxapyroxad, furametpyr, isopyrazam, mepronil, oxycarboxin, penflufen, penthiopyrad, 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 antiresistance 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.

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 *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.

3.6 SDHI Guidelines - Banana

Guidelines for the use of SDHI fungicides in banana are published by the Banana FRAC working group and can be found on the FRAC website under Banana Working Group (the next meeting is scheduled for 2014).

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 for the first time 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 as defined in the FRAC Pathogen Risk List found on the FRAC Website under publications.

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 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.

3.9. Seed treatment for other crops

FRAC will develop recommendations for other crops in upcoming meetings.