



Summary of Fungicide Resistance Management Guidelines by FRAC Working Group (WG) and Expert Fora (EF) relevant for Cereals and Corn

The Fungicide Resistance Action Committee (FRAC) is a Specialist Technical Group of CropLife International. The purpose of FRAC is to provide fungicide resistance management guidelines to prolong the effectiveness of "at risk" fungicides and to limit crop losses should resistance occur.

FRAC Guidelines for resistance management are produced by the individual FRAC Working Groups and Expert Fora. These Guidelines provide information on how to use fungicides sharing the same mode of action for the control of plant diseases on various crops in order to maximize the durability of these products.

The relevant **general** and **crop-specific** Guidelines for a crop are compiled in this document, in order to make them more easily accessible to crop-focused stakeholders such as policy makers, private as well as industry advisors, retailers and farmer associations.

The following general and crop-specific Guidelines given by the individual FRAC Working Groups and Expert Fora as well as recommendations provided by manufacturers to FRAC are compiled in this document.

Recommendations from Working Group (WG) or Expert Fora (EF) Meeting minutes included in this document	Meeting Date (dd.mm.yyyy)
Recommendations provided by manufacturers to FRAC	No FRAC meetings
Benzimidazole FRAC EF - General Use Recommendations	No regular meetings
Phenylamides FRAC EF - General Use Recommendations	No regular meetings
QoI FRAC WG Recommendations	03.03.2021
SBI FRAC WG Recommendations	03.03.2021
SDHI FRAC WG Recommendations	21.01.2021

For further information please refer to most recent version of the Guidelines on www.frac.info.

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Listing of chemical classes or modes of action in any of the CropLife International/RAC recommendations must not be interpreted as approval for use of a compound in a given country. Prior to implementation, each user must determine the current registration status in the country of use and strictly adhere to the uses and instructions approved in that country.

Azanaphthalenes - Use Recommendations for Cereals (30th of March 2020) (Quinoxyfen, Proquinazid)

- Apply Group 13 fungicides preventatively.
- Apply a maximum of 2 Group 13 fungicides containing sprays per crop solo or in mixture (coformulations or tank mixes) with effective mixture partners from different cross-resistance groups.
- If a second application is needed, it should be in tank-mix with an effective powdery mildewcide with another mode of action.
- Always follow product-specific label recommendations for resistance management.

Benzimidazoles – General Use Recommendations

Due to the widespread incidence of benzimidazole resistance in many fungal populations, good resistance management practices must be implemented as soon as possible in order to delay or prevent further changes in sensitivity in the target pathogens.

There are no specific recommendations for benzimidazoles. Both mixtures and alternations are valid strategies to minimize the risk of resistance development. In case of tank-mixtures, the benzimidazole fungicide must be applied at its label dose together with the appropriate dose of an effective, non-cross-resistant partner fungicide. Benzimidazole-based products must be integrated in a spray program containing fungicides having a different site of action and effective on the target pest. In order to reduce selection pressure, the total number of benzimidazole applications should not exceed that indicated on the product label. The exclusive use of benzimidazole fungicides must be avoided. Post-infection, curative treatments must be reserved for special situations where no alternatives are available.

The above recommendations must be integrated in an overall disease management program combining appropriate methods of cultural, biological as well as chemical disease control. Implementation of the above strategies must take into account the particular characteristics of the crop, pest and geographic area in which the benzimidazole product is to be applied.

Phenylamides – General Use Recommendations

The general use recommendations for phenylamide-based products have remained unchanged since 1997. The key (“umbrella”) guidelines for product use are as follows (they have to be adapted to local requirements and resistance levels):

Seed treatment:

- PA used as seed treatment is considered in general lower risk of resistance development.
- However, foliar or soil drench applications of PA containing products in the previous crop can influence the sensitivity situation particularly in vegetable crops.
- Careful planning of the crop rotation and the respective PA usage during the season is recommended in order to lower the selection pressure on the soil population of *Pythium* spp. Applying PA containing products in e.g. spinach, beans, cauliflower, can accelerate PA resistance for the following crop planting, e.g. corn. Cereals, rape or grassland as a previous crop do not negatively affect PA sensitivity.
- For seed treatment, mixtures rather than straight phenylamides should be used whenever possible.
- The phenylamides should not be used as soil treatments against foliar diseases. When solo formulations are made available for soil use, strategies must be implemented which prevent any possibilities for foliar applications.

Qil (Quinone inside Inhibitors) - Recommendations for cereals (Apr. 17th 2019) (Fenpicoxamid)

- Apply picolinamides preventatively.
- Apply a maximum of 1 picolinamide containing spray per crop. Fenpicoxamid should always be applied in mixture (co-formulation or tank mix) with a partner(s) from a different cross-resistance group which provide(s) robust control of *Zymoseptoria tritici*.
- Always follow product-specific label recommendations for resistance management.

QoI – Strategies and Guidelines for cereals

Where the guidelines were followed, field performance of QoI containing spray programmes was good. It continues to be essential to use non-cross resistant mixture partners (e.g. SBIs, multi-sites) to ensure robust disease management. This will also help to delay the evolution of resistance, especially in regions with no resistance or where resistance is at low levels.

Therefore, the recommendations remain unchanged.

Guidelines for using QoI fungicides on cereal crops:

- Apply QoI fungicides always in mixtures with non-cross resistant fungicides to control cereal pathogens. At the rate chosen the respective partner(s) on its/ their own has/ have to provide effective disease control. Refer to manufacturers recommendations for rates.
- Apply a maximum of 2 QoI fungicide containing sprays per cereal crop. Limiting the number of sprays is an important factor in delaying the build-up of resistant pathogen populations.
- Apply QoI fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated.
- Apply the QoI fungicide preventively or as early as possible in the disease cycle. Do not rely only on the curative potential of QoI fungicides.
- Split / reduced rate programmes, using repeated applications, which provide continuous selection pressure, accelerate the development of resistant populations and therefore must not be used.

In addition to the crop specific recommendations, general recommendations for this mode of action have to be considered, which are located at the end of this document.

SBI Recommendations for cereals (DMIs and amines)

The recommendations for the use of DMI and amine fungicides in mixture or alternation programmes with different mode of action fungicides remain unchanged. It needs to be emphasized that it is essential for resistance management purposes to follow strictly the manufacturer's and FRAC recommendations.

Repeated application of DMI or amine fungicides alone should not be used on the same crop in one season against risky pathogens (e.g. cereal powdery mildews, barley net blotch, scald) in areas of high disease pressure for that particular pathogen.

Reduced rates of DMIs can contribute to accelerate the shift to less sensitive populations. It is critical to use effective rates of DMIs in order to ensure robust disease

control and effective resistance management. DMIs must provide effective disease control and be used at manufacturers recommended rates.

When used in mixture recommended effective rates of the SBI must be maintained. Split and reduced rate programmes, using multiple repeated applications at dose rates below manufacturer's recommendations, provide continuous selection pressure and accelerate the development of resistant populations, and therefore must not be used.

To ensure good performance and particularly resistance management in situations of even low disease pressure it is essential to adhere to dosages and spray timings as recommended by manufacturers. Curative applications should be avoided. Application timing has to be appropriate to all mix partners' characteristics. Mixing with a non-cross resistant fungicide at effective dose rates contributes to a more effective disease control and resistance management.

The amine fungicides are effective non-cross-resistant partner fungicides for DMIs on cereals for the control of pathogens included in the label recommendation of each respective product.

In addition to the crop specific recommendations, general recommendations for this mode of action have to be considered, which are located at the end of this document.

SDHI-Guidelines – Cereals

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.

In addition to the crop specific recommendations, general recommendations for this mode of action have to be considered, which are located at the end of this document.

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.

General guidelines and recommendations

In addition to the crop specific recommendations mentioned above, general recommendations for the following modes of action have to be considered:

Qo1 – General Strategies and Guidelines for the 2021 season

Strategies for the management of Qo1 fungicide resistance, in all crops, are based on the statements listed below. These statements serve as a fundamental guide for the development of local resistance management programs.

Resistance management strategies have been further enhanced in order to be proactive and to prevent the occurrence of resistance to Qo1 fungicides developing in other areas and pathogens. Specific guidelines by crop follow the general guidelines given here.

A fundamental principle that must be adhered to when applying resistance management strategies for Qo1 fungicides is that:

- The Qo1 fungicides (azoxystrobin, coumoxystrobin, dimoxystrobin, enoxastrobin, famoxadone, fenamidone, fenaminostrobin, fluoxastrobin, flufenoxystrobin, kresoxim-methyl, mandestrobin, metominostrobin, orysastrobin, pyraoxystrobin picoxystrobin, pyraclostrobin, pyrametastrobin, pyribencarb, triclopyricarb trifloxystrobin) are in the same cross-resistance group; FRAC Code 11
- The Qo1 fungicide in subgroup A (metyltetraprole), Code 11A fungicide, is not cross-resistant with Code 11 fungicides in pathogens with G143A mutation.
- Fungicide programmes must deliver effective disease management. Apply Qo1 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 Qo1 fungicide based products within a total disease management program must be limited whether applied solo or in mixtures with other fungicides. This limitation is inclusive to all Qo1 fungicides. Limitation of Qo1 fungicides within a spray programme provides time and space when the pathogen population is not influenced by Qo1 fungicide selection pressure.
- Limitation of the total number of Qo1 applications is detailed in the specific crop recommendations. In consideration of the cross-resistance profile of subgroups 11 and 11A, the maximum allowed number of Qo1-containing sprays is increased by one, where both Qo1 fungicides (code 11) and Qo1 fungicides in subgroup A (code 11A) are included in a spray program in a given cropping season. All crop-specific recommendations will be regularly reviewed based on sensitivity monitoring.

- A consequence of limitation of Qo1 fungicide based products is the need to alternate them with effective fungicides from different cross-resistance groups (refer to the specific crop recommendations).
- Qo1 fungicides, containing only the solo product, should be used in single or block applications in alternation with fungicides from a different cross-resistance group. Specific recommendation on size of blocks is given for specific crops.
- Qo1 fungicides, applied as tank mix or as a co-formulated mixture with an effective mixture partner, should be used in single or block applications in alternation with fungicides from a different cross-resistance group. Specific recommendations on size of blocks are given for specific crops.
- Mixture partners for Qo1 fungicides should be chosen carefully to contribute to effective control of the targeted pathogen(s). The mixture partner must have a different mode of action, and in addition it may increase spectrum of activity or provide needed curative activity. Use of mixtures containing only Qo1 fungicides (including two-way mixtures of code 11 fungicide and code 11A fungicide) must not be considered as an anti-resistance measure.
- An effective partner for a Qo1 fungicide is one that provides satisfactory disease control when used alone on the target disease.
- Qo1 fungicides are very effective at preventing spore germination and should therefore be used at the early stages of disease development (preventive treatment).

SBI – General recommendations for use

The SBI fungicides represent one of the most potent classes of fungicides available to the grower for the control of many economically important pathogens. It is in the best interest of all those involved in recommending and using these fungicides that they are utilised in such a way that their effectiveness is maintained

The Working Group concentrates its resources on the major crop/pathogen targets from the point of view of resistance risk. Inevitably many, still important pathogens are omitted. To help in making recommendations for crops and pathogens not directly covered, the following general recommendations can be made:

- Repeated application of SBI fungicides alone should not be used on the same crop in one season against a high-risk pathogen in areas of high disease pressure for that particular pathogen.
- For crop/pathogen situations where repeated spray applications (e.g. orchard crops/powdery mildew) are made during the season, alternation (block sprays or in sequence) or mixtures with an effective non cross-resistant fungicide are recommended.

- Where alternation or the use of mixtures is not feasible because of a lack of effective or compatible non cross-resistant partner fungicides, then input of SBI's should be reserved for critical parts of the season or crop growth stage.
- If the performance of SBIs should decline and sensitivity testing has confirmed the presence of less sensitive isolates, SBIs should only be used in mixture or alternation with effective non cross-resistant partner fungicides.
- The introduction of new classes of chemistry offers opportunities for more effective resistance management. The use of different modes of action should be maximized for the most effective resistance management strategies.
- Users must adhere to the manufacturers' recommendations. In many cases, reports of "resistance" have, on investigation, been attributed to cutting recommended use rates, or to poorly timed applications.
- Fungicide input is only one aspect of crop management. Fungicide use does not replace the need for resistant crop varieties, good agronomic practice, plant hygiene/sanitation, etc.
- Exclusive frequency measurements of single cyp51 mutations are not sufficient to describe the sensitivity situation towards DMIs but can help to better understand the background of sensitivity shifts.

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, cyclobutirfluram, 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.