



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

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)
Benzimidazole FRAC EF - General Use Recommendations	No regular meetings
Dicarboximides 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.

Disclaimer

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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.

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.

Dicarboxamides – General Use Recommendations

- Minimise the selection pressure by minimising the number of applications. As a guide, do not apply more than two to three per crop per season.
- Restrict applications to those times when Botrytis infection pressure is high.
- Maintain regular prolonged times without exposure to dicarboximides.
- Where resistance is well established, use combinations to stabilise Botrytis control, but their application must follow the same rules as for dicarboximides alone.

Note that individual countries will now have their own, more detailed, use guidelines for specific crops.

Qol – Guidelines for use on soybean diseases

Qol fungicides control soybean diseases including rust, which is a major disease in Latin America and has been detected recently in the USA.

In order to ensure sustainable use of Qols the Working Group recommends:

Apply Qol fungicides according to manufacturer's recommendations for the target disease (or complex) at the specific crop growth stage indicated. Effective disease management is a critical parameter in delaying the build-up of resistant pathogen populations.

1. Use Qols preventatively or as early as possible in the disease cycle.
2. Use Qols preferably in mixtures (co-formulations or, where permitted, tank mixes) with fungicides from a different cross-resistance group. At the rate chosen each partner on its own has to provide effective disease control. Refer to manufacturers' recommendations for rates. In regions where target site mutations in key target soybean pathogens are present mixtures are mandatory.
3. Limiting the number of sprays containing Qol fungicides is an important factor in delaying the build-up of resistant pathogen populations.

Good agricultural practices must be considered to reduce source of inoculum, disease pressure and resistance risk, e.g. no multiple cropping, implement and respect soybean-free periods, consider varietal tolerance, reduce the planting window, give preference to early-cycle varieties or endorse the destruction of volunteers.

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 Asian soybean rust:

Refer to the general recommendations for SBI's.

In addition, to ensure robust disease control and resistance management it is essential to

- Apply DMI fungicides always in mixtures with effective non-cross-resistant fungicides (mix partner shall provide control over the spraying interval).

- Refer to manufacturers recommendations for rates. Reduced rates must be avoided.
- Apply preventively or as early as possible in the disease cycle.
- Ensure a proper coverage of the treated crop by appropriate and well calibrated application technology (e.g. to ensure penetration into canopy).
- Apply DMI fungicide containing products always at intervals recommended by the manufacturers and adjusted to the disease epidemics. Avoid extended spray intervals.
- Good agricultural practices must be considered to reduce source of inoculum, disease pressure and resistance risk, e.g. no multiple cropping, implement and respect soybean-free periods, consider partially resistant soybean varieties, reduce the planting window, give preference to early-cycle varieties and endorse the destruction of volunteers.

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 – 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.

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.

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:

QoI – General Strategies and Guidelines for the 2020 season

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

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

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

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

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

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, cyclobutrifluram, 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.