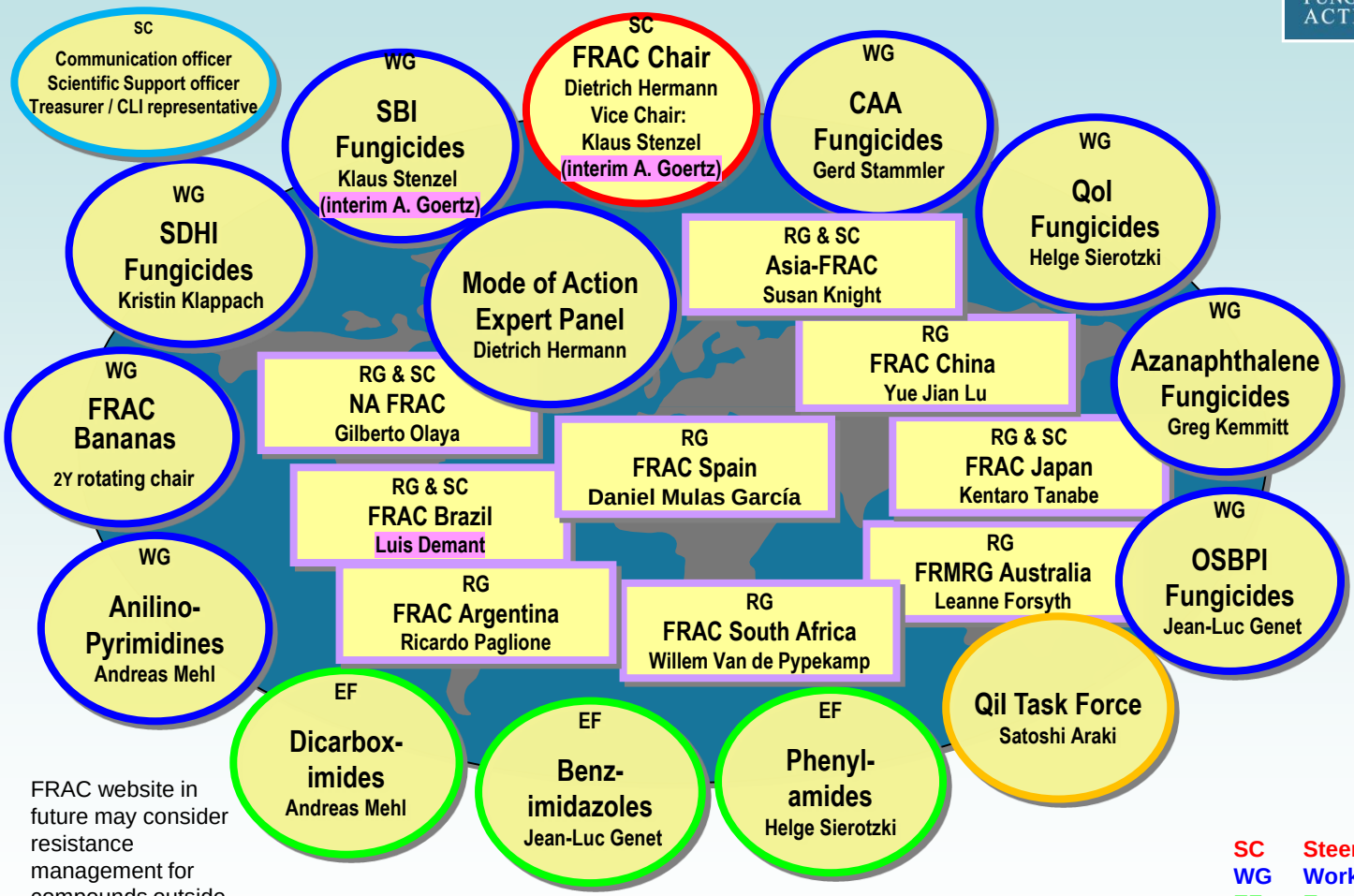
2019 FRAC Update

EPPO Resistance Panel

Rothamsted, 19 September 2019

Organization of FRAC – What's New?



FRAC website in future may consider resistance management for compounds outside WGs/EF

SC Steering Committee
WG Working Group
EF Expert Forum
RG Regional FRAC Group

FRAC Steering Committee 2019

Name	Company	FRAC Role
Dr. D. Hermann	Syngenta	Chairman FRAC, Chairman MoA Expert Panel
Dr. K. Stenzel (interim A. Goertz)	Bayer	Vice Chairman FRAC, Chairman SBI Fungicides WG
Mr. D. McKenzie		Scientific Support Officer
Dr Anika Bartholomaeus	Bayer	FRAC Treasurer
Dr. J. Derpmann	Bayer	Communication and Website Officer
Dr. G. Kemmitt	Corteva	Chairman Azanaphthalene WG; FRAC-MoA Poster
Dr. A. Mehl	Bayer	Chairman Anilinopyrimidines WG & Dicarboximide Expert Forum
Dr. G. Stammler	BASF	Chairman CAA Fungicides WG
Dr. Kristin Klappach	BASF	Chairwoman SDHI Fungicides WG
Dr. H. Sierotzki	Syngenta	Chairman QoI-WG & Phenylamides Expert Forum
Mr. J.-L. Genet	Corteva	Chairman OSBPI-WG & Benzimidazoles Expert Forum
Dr. K.-H. Lorenz	BASF	Chairman Banana FRAC 2018-20
Dr. K. Tanabe	Nippon Soda JP	Representative Japan FRAC (Chair), QiI Task Force representative
Dr. G. Olaya	Syngenta USA	Representative North America FRAC (Chair)
Mr. L. Demant	FMC Brazil	Representative Brazil FRAC (Chair)
Dr. Susan Knight	Syngenta APAC	Representative Asia FRAC (Chair)
Mr. A Ward	*CLI*	*Stewardship director, CLI representative*

Change

New

Organization of FRAC – What's New?

- FMC (Henry Ngugi) and Sumitomo (Ippei Uemura) now on the FRAC steering committee
- Bayer expressed the wish to join the FRAC OSBPI working group (fluoxapiprolin) in 2020

New FRAC definition of Resistance

Published on FRAC webpage in Nov 2018

Definition of fungicide resistance

The term **fungicide resistance**, as used by FRAC, refers to an acquired, heritable reduction in sensitivity of a fungus to a specific anti-fungal agent (or fungicide). This results in a change in the sensitivity of a fungus to a specific fungicide mode of action which is generally brought about by selection pressure being applied by the specific fungicide mode of action on the fungus in question, in time and space (often due to prolonged and wide spread exposure of the fungus to the specific fungicide mode of action). Such changes may be detected in populations or only in single isolates.

The understanding of the process of selection in itself indicates that resistant isolates of a fungus are present in the natural population (i.e. not having been exposed to the specific fungicide MoA). These isolates develop through natural / random mutations and the specific fungicide mode of action selects them through exposure.

FRAC gives clear differentiation between resistance which has been artificially generated under controlled conditions (in the laboratory) and that which is selected in the field following use of the specific fungicide.

Lab resistance, where a fungus with lower sensitivity has been generated using various methods in the laboratory. These fungicide resistance organisms are predominantly of academic importance. The resistance developed in the lab can differ from that found in the field but their occurrence could be extended to the field in time. Reports on such studies should be clearly stated as being laboratory studies.

Field resistance, refers to changes (in sensitivity) that occur in a specific fungus under natural conditions. The first indications of the possibility of field resistance may be found through routine monitoring. Poor performance on its own is however not evidence of resistance and this has to be shown by scientific studies.

Serious field performance problems occur when the fungal population is altered from being predominantly sensitive to being predominantly resistant. In addition to the frequency of resistance, different mechanisms of resistance are possible, each with a particular resistance factor. Both frequency and resistance factor contribute to the field performance of the fungicide. This change in sensitivity will also largely depend on the ability of the resistant isolates to survive and reproduce (i.e. the general fitness of the resistant isolates).

To manage resistance effectively, scientists study fungicide resistance on many different levels including the cellular, organismal or population / field level. Reports of field failures assumed to be caused by "resistance" (i.e. where growers observed reduced efficacy of a product that has previously demonstrated efficacy against that particular pathogen) must be confirmed by lab studies on the organisms, thereby excluding other factors which may influence fungicide performance.

The development of fungicide resistance is a natural evolutionary process. This can happen relatively rapidly in fungi as their reproduction rate is relatively high. The fungicide exerts **selection pressure** on the pathogen population by killing the initial (or **wild type**) population and not affecting the changed (or **mutant)** population. When changes are slightly disadvantageous under normal conditions (i.e. in the absence of the fungicide), the frequency of the changed population may decrease when the selection pressure is removed. This is termed a **fitness penalty.**

New FRAC website (in progress)

FRAC

FUNGICIDE RESISTANCE ACTION COMMITEE

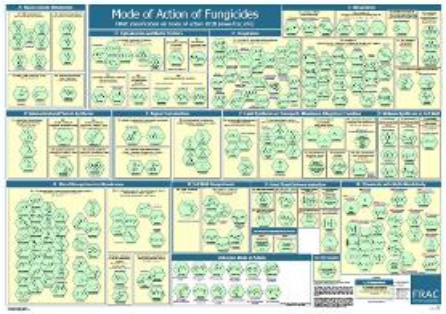
Search

Home | Fungicide Resistance Management | Knowledge Database | FRAC-Teams | Contacts

Background information →

Recommendations for resistance management →

Summary of annual Sensitivity Monitoring →

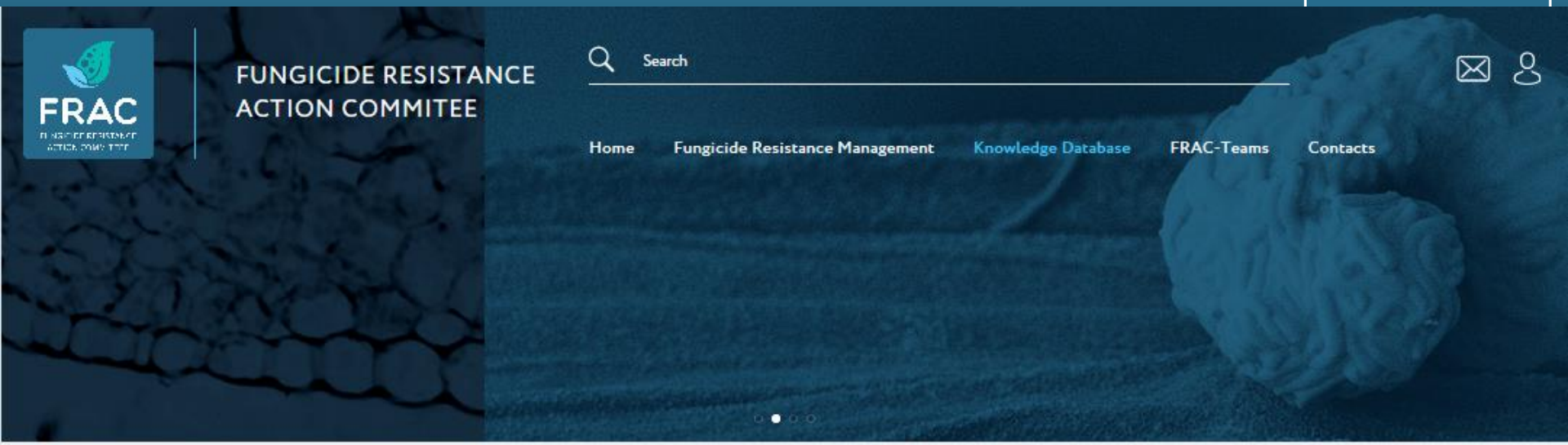


FRAC Poster ©

FRAC Code List ®

FRAC Pathogen Risk List

New FRAC website (in progress)



Knowledge Database > Summary of annual Monitoring

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Summary of annual Sensitivity Monitoring

In order to generate recommendations for fungicide resistance management, the member companies of FRAC share sensitivity monitoring data. This process is done under strict anti-trust guidelines. The summary of the Sensitivity Monitoring as well as the resulting FRAC Recommendations for Fungicide Resistance Management are published annually in Minutes of the Working Group meetings, which are public available for download:

Minutes of the SBI Meetings

	Sterol biosynthesis inhibitor (SBI) fungicides:
GROUP 3	SBI Class I: DMI-fungicides (DeMethylation Inhibitors)
GROUP 5	SBI Class II: Amines ("Morpholines")
GROUP 17	SBI Class III: KRI fungicides (KetoReductase Inhibitors)
GROUP 18	SBI Class IV: Squalene-epoxidase in sterol biosynthesis

Start typing . . .

	Name	Type
PDF	Minutes of the 2017 SBI Meeting Recommendations for 2018	PDF

FRAC Recommendations for Resistance Management

Fungicide resistance management strategies must combine the long-term conservation of fungicide effectiveness with an amount and pattern of use that are sufficient to satisfy the needs of the farmer.

Thus to have a chance of success, any strategy must be reached by agreement and depend upon a commitment to implementation from all supply companies involved. Also, it must be understandable and acceptable to the farmer.

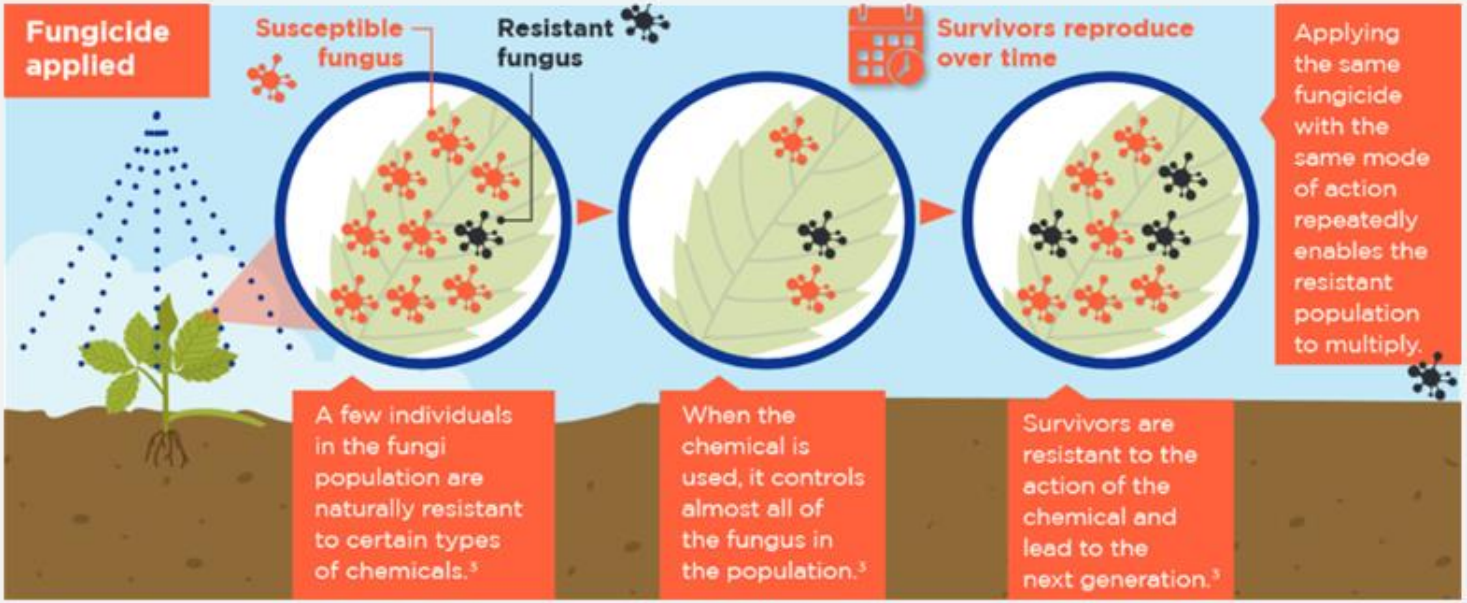
FRAC provides background information as well as annually updated Fungicide Resistance Management Recommendations for fungicides of the major modes of action:

Search Fungicides to find Recommendations →

Search Mode of Action to find Recommendations →

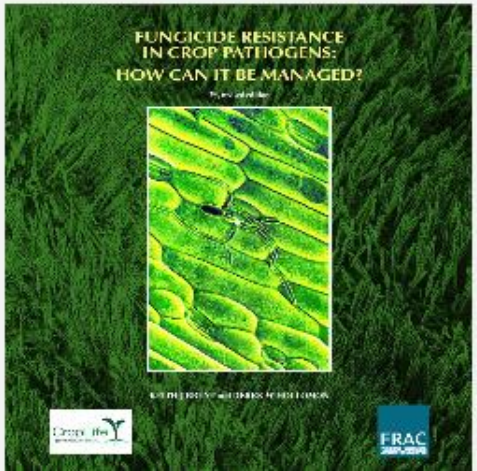
Search Crops to find Recommendations →

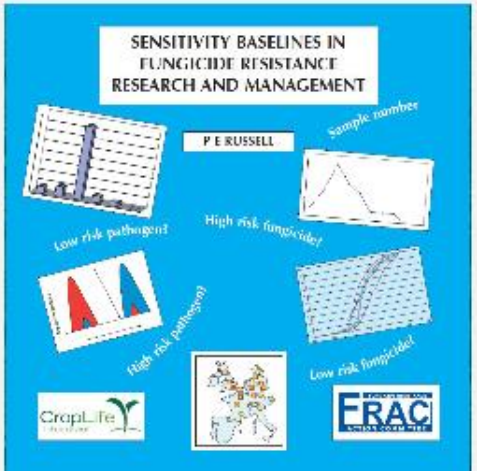
How does Fungicide Resistance evolve?



Source: CropLife International

Evolution of fungicide resistance is an even more complex process than visualized above. It is depended on various factors like cropping system, pathogen, fungicide, climate and most importantly the farmers decision to implement a resistance management strategy.
The following publications give an overview on the world-wide efforts to combat problems in crop protection that are caused by development of resistance to fungicides:





New FRAC website (in progress)

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Fungicide Resistance Management > By selected Crops

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Search FRAC Recommendations by Crop

Banana

Grapevine

Soybean

Contact

Summary of Recommendations for Grapevine

11th of April, 2019

This document is automatically generated from the following FRAC Working Groups Recommendations. For further information please refer to the links in the list of the individual recommendations:

Fungicide groups to control diseases caused by true fungi	
Anilino-Pyrimidines (AP)	Link to all AP-Recommendations
Aza-naphthalenes (AZN)	Link to all AZN-Recommendations
Dicarboximide fungicides	Link to all Dicarb.-Recommendations
MBC fungicides (Methyl Benzimidazole Carbamates) and NPC fungicides (N-phenyl carbamate)	Link to all MBC-Recommendations
Sterol biosynthesis inhibitor (SBI) fungicides, Azoles	Link to all SBI-Recommendations
Succinate dehydrogenase inhibitors (SDHI)	Link to all SDHI-Recommendations
Quinone outside Inhibitors (QoI), Strobilurines	Link to all QoI-Recommendations
Fungicide groups to control diseases caused by oomycetes	
Carboxylic Acid Amides (CAA)	Link to all CAA-Recommendations
OxySterol Binding Protein Inhibition (OSBPI)	Link to all OSBPI-Recommendations
PhenylAmide fungicides (PA)	Link to all PA-Recommendations
Quinone outside Inhibitors (QoI), Strobilurines	Link to all QoI-Recommendations

Search by FRAC Mode of Action Groups for Recommendations

The FRAC Mode of Action (MoA) classification provides growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of fungicides for use in an effective and sustainable fungicide resistance management strategy.
To find Recommendations for Resistance Management in Bananas, please follow the following link:
Link to Recommendations for Resistance Management in Banana.
Get forwarded to FRAC Recommendations for Fungicide Resistance by clicking in the table below based on Mode of Action, FRAC MoA Group name or FRAC Code number as printed on label of Plant Protection Products:

Labelling	FRAC acknowledged Mode of Action (MoA) and links to Recommendations for FRAC MoA Groups
	Inhibitor of ß-tubulin assembly in mitosis:
GROUP 1	MBC fungicides (Methyl Benzimidazole Carbamates)
GROUP 10	NPC fungicides (N-phenyl carbamate)
	Inhibitor of osmotic signal transduction
GROUP 2	Dicarboximide fungicides
	Sterol biosynthesis inhibitor (SBI) fungicides:
GROUP 3	SBI Class I: DMI-fungicides (DeMethylation Inhibitors)
GROUP 5	SBI Class II: Amines ("Morpholines")
GROUP 17	SBI Class III: KRI fungicides (KetoReductase Inhibitors)
GROUP 18	SBI Class IV: Squalene-epoxidase in sterol biosynthesis
	Inhibitor of RNA polymerase I
GROUP 4	PA fungicides (PhenylAmides)
	Inhibitor of respiration in complex II at SDH
GROUP 7	SDHI fungicides (Succinate dehydrogenase inhibitors)
	Inhibition of methionine biosynthesis (proposed)
GROUP 9	AP fungicides (Anilino-Pyrimidines)
	Inhibitor of respiration in complex III at Qo-site
GROUP 11	QoI-fungicides (Quinone outside Inhibitors)

Search Fungicides to find FRAC Recommendations

The FRAC Mode of Action (MoA) classification of fungicides provides growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of fungicides for use in an effective and sustainable fungicide resistance management strategy.

Link to Recommendations for Resistance Management in Banana.

To help navigate through the chemical diversity of fungicides, a search for the fungicide common name in the search-field below will present important information needed for resistance management of the selected fungicide:

- To which FRAC MoA group belongs the selected fungicide.
- Which other fungicides belong to the same FRAC MoA Group, thus having a degree of cross resistance. Fungicides of the same FRAC MoA Group are no suitable mixing or alternating partner for resistance management.
- The intrinsic risk of the selected fungicide used for resistance risk analysis of fungicides (low, medium or high), which define the need for resistance management
- Comments on known (molecular) resistance mechanism and resistant pathogens (full list, please look here)
- Link to the annually updated FRAC Recommendations for Resistance Management

Filter:

Groups...

A	Nucleic acids metabolism
B	Cytoskeleton and motor proteins
C	Respiration
D	Amino acids and protein synthesis

pyraziflumid
pyrazophos
pyribencarb
pyributicarb
pyrifenox

Resistance Management Recommendations for Modes of Action not covered by FRAC Working Groups

This section contains FRAC approved company resistance management recommendations for fungicide MoAs not covered by an active working group. Please refer to the FRAC Code List for important comments on resistance management.

- Which Fungicides belong to the same FRAC MoA Group. Fungicides of the same FRAC MoA Group are expected to demonstrate a degree of cross resistance once field resistance arises. They are thus not seen as suitable mixing or alternating partners for resistance management purposes.
- The intrinsic risk of the MoA group, to be used for resistance risk analysis of fungicides ('low', 'medium' or 'high'); which defines the need for resistance management.
- Comments on known (molecular) resistance mechanisms and resistant pathogens (full list, please look here)

For some Mode of Action Groups the manufacturers provided FRAC with recommendations:

PDF Group 13 (E1) - Aza-naphthalenes (AZN) Recommendations April 5th 2018

PDF Group 21 (C4) - Fenpicoxamid (QiI) Recommendations 17th of April 2019

PDF Group 21 (C4) - amisulbrom, cyazofamid (QiI) Recommendations 2nd of May 2019

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What`s new

06.17.2019

Minutes and recommendations of the OSBPI Working Group are now available

Minutes and recommendations of the OSBPI Working Group from the meeting on April 3rd are now available.
The summary of monitoring-data for OSBPIs is given in the minutes (link).
No further changes were made to OSBPI WG recommendations for 2019 (link) compared that published in 2018.

03.12.2019

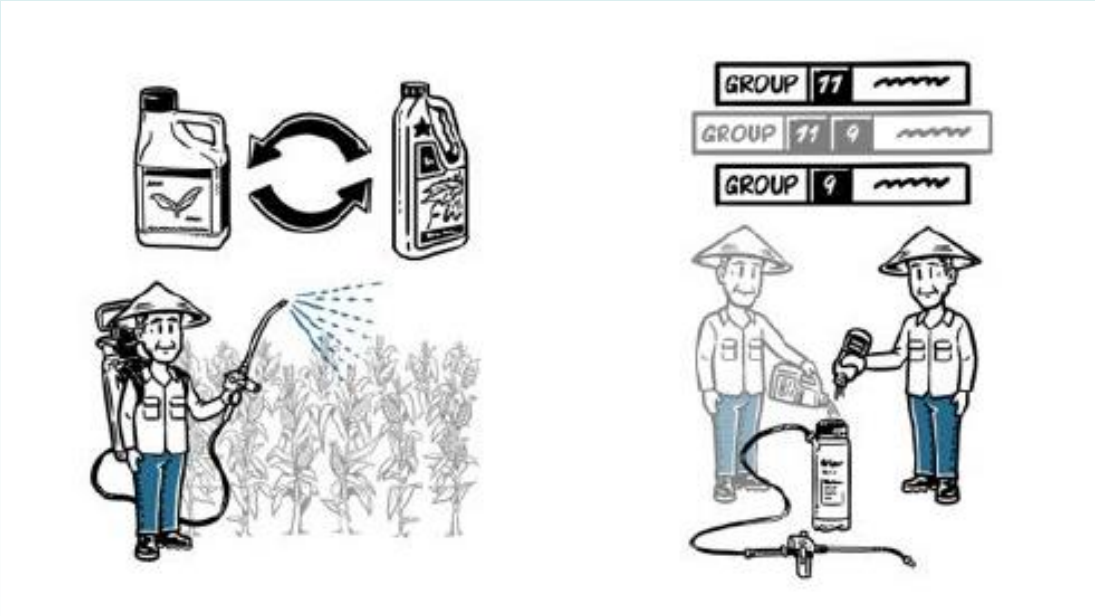
Minutes and guidelines of the Banana Working Group are now available in Spanish

Minutes and guidelines of the Banana Working Group (WG) from the meeting on April 30th to May 1st 2018 are now available in Spanish.

A summary of monitoring-data is given in Spanish in the Banana WG minutes (link).

New FRAC video in preparation

- Similar to the IRAC version but using a newer platform.
- 3 minutes maximum
- Script is ready
- Considering English, Spanish and Mandarin versions. Other languages may be added later



- Pathogen risk list is being updated
- Not yet published on the FRAC website

Pathogen	Crop	Disease
Albugo candida	Brassica species	white rust
Alternaria brassicicola, A. brassicae	oilseed rape and cabbage	black leaf spot, dark leaf spot
Alternaria solani	potato, tomato	early blight
Ascochyta pisi	peas	Ascochyta blight
Bipolaris maydis	maize	leaf blight
Blumeriella jaapii	sour cherry	leaf spot
Bremia lactucae	lettuce	downy mildew
Cercospora beticola	sugar beet	leaf spots
Cercospora kikuchii	peanuts, beans, various	leaf blight
Cercospora sojina	soybean	frogeye leaf spot
Colletotrichum acutatum	several	anthracnose
Colletotrichum gloeosporoides	various	anthracnose
Drepanopeziza ribis	currants	leaf spot
Elsinoe spp.	citrus	citrus scab
Erysiphe cruciferarum	powdery mildew	various
Erysiphe heraclei	powdery mildew	carrot
*Erysiphe necator**	grapevine	powdery mildew
*Gibberella fujikuori**	rice	bakanae
Gloeosporium spp. (G. fructigenum, G. album)	pomefruits	storage diseases
Leveillula taurica	pepper	powdery mildew
Microdochium nivale	cereals, turf	snow mold
Monilinia spp.	various	blossom and fruit rot
Mycosphaerella brassicicola	crucifer	ringspot
Mycosphaerella graminicola (Zymoseptoria tritici)	wheat	leaf spot
Mycosphaerella musicola	banana	yellow sigatoka
Mycosphaerella nawae	kaki	circular leaf spot
Mycosphaerella pinodes	pea	blight, purple spot
Mycovellosiella nattrassii	eggplant	leaf mold
Oculimacula spp.	wheat/barley	eyespot
Oidium neolycopersici	tomatoes	powdery mildew
Penicillium digitatum	various	green mold
Penicillium expansum	various	blue mold

high risk | **medium risk** | low risk

FRAC Code List & Poster

- The FRAC poster is being redesigned
- Title and introduction adjusted to emphasize focus on cross-resistance rather than Mode of Action
- Mefentrifluconazole be classed as code 3
- Sumitomo to provide their input regarding the coding for metyltetraprole (QoI not cross-resistant with existing QoIs).
- Update/amendments for the anilinopyrimidines will be considered after the publication expected in 2019.
- Two groups for Biologicals:
  - Plant extracts
  - Microoganisms
- Several new molecules considered for addition

FRAC Spain

- A Spanish leaflet on fungicide MoA was published and is available on request.
- Spain plan to introduce an APP similar to the global version but specific to Spain and Spanish registrations.
- Spain is also preparing a list of resistance cases for important pathogens and crops in Spain.
- Spain is also in the process of developing an alert for *Botrytis* starting with strawberries.

Asia FRAC

- Held their second meeting on March 14, 2019.
- Priority countries for 2019: India, Korea, Vietnam
- Crop-based resistance management guidelines to be finalized (example on next slide)
- XIX International Plant Protection Congress, 10-14 Nov, Hyderabad, India

Fungicide Resistance Management Guidelines: Rice

FUNGICIDES: IMPORTANT TOOLS FOR PREVENTING AND MANAGING PLANT DISEASE

RICE DISEASE MANAGEMENT: Adopt an integrated approach to disease and crop management to **avoid over-reliance on too few fungicidal modes of action**, which increases the risk of selecting resistant strains.

GENERAL DISEASE MANAGEMENT GUIDELINES

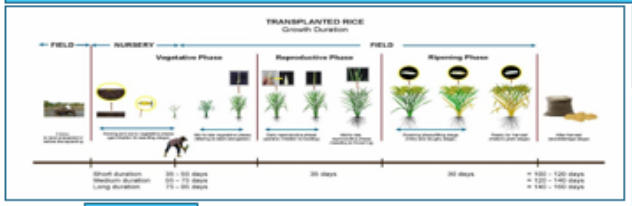
- Use clean seed that is free of infection (particularly in areas affected by blast, bakanae or *Helminthosporium oryzae*)
- Remove or destroy primary infection sources, e.g. left-over seedlings, infested straw and chaff
- Make fungicide applications based on favourable weather for disease development, rice growth stage or local disease warnings (prevent disease instead of treating after symptoms appear)
- Control seedling and leaf blast to reduce neck blast severity
- Avoid excessive nitrogen fertilizer (follow local guidelines)
- Control weeds (these may be host plants for pathogens, especially on levees)
- Avoid high seeding /transplanting density (follow local guidelines)

RESISTANCE MANAGEMENT GUIDELINES: RICE FUNGICIDES

- Manage resistance by alternating or mixing (premix or tank mix, if permitted) fungicides from different mode of action groups, that are effective against the target pathogen at the label recommended rates
- The risk that resistance will develop to the following types of product is low, and there are no resistance management restrictions: multisite fungicides, biologicals and inducers of host plant resistance
- For all other modes of action, avoid using fungicides from the same mode of action group for more than 50% of the total number of applications, and follow product labels and specific FRAC guidelines for each mode of action group (http://www.frac.info/)
- Do not apply Group 11 fungicides for seed production.
- If resistance has been confirmed in a location, do not apply solo fungicides from that mode of action group to control the resistant population

Government recommendations and product labels must be followed, and always supersede the above guidelines.

Using fungicides in a programme for resistance management in rice



Seedling disease

Leaf blast (*Pyricularia oryzae*)

Neck & panicle blast (*Pyricularia oryzae*)

Sheath blight (*Rhizoctonia solani*)

Brown spot (*Helminthosporium oryzae*)

Narrow brown spot (*Cercospora oryzae*)

False smut (*Ustilaginoidea virens*)

Dirty panicle (complex)

Fungicides that are effective for rice disease control belong to the modes of action listed below*

- Only use registered fungicides & follow label directions

Disease target	Recommended maximum no. of applications for disease management	Minimum recommended no. of available modes of action for resistance management	Registered modes of action (FRAC Code)
Pyricularia oryzae	2-4	3	8, 11, 16.1, 16.2, 16.3, 23, 24, 32
Foliar disease complex	2-4	2-3	1, 3, 7, 11, 20, 24, 25, U18
Grain disease complex	1-2	2	1, 3, 7, 11

* TO BE CUSTOMIZED BY EACH COUNTRY: ONLY INCLUDE MODES OF ACTION WITH REGISTERED PRODUCTS

Status of resistance to rice fungicides

Rice blast (Pyricularia oryzae)

High-risk pathogen; resistance reported to some modes of action:

- Resistance reported to Group 11 fungicides (Japan, 2012 & Vietnam, 2015); no resistance reported from China, India, Indonesia & Philippines*
- Resistance reported to Group 6 fungicides (China, Japan)**, Group 16.2 fungicides (Japan)*** and Group 24 fungicides (Japan) ****
- No resistance has been reported to Group 16.1 fungicides

Other rice pathogens - few reports of fungicide resistance

- Resistance reported in *Gibberella fujikuroi* (bakanae disease) to Group 1 fungicides (China, Japan, S. Korea)***** and Group 3 fungicides (China, Korea)******
- Localized resistance to Group 11 fungicides reported in *Rhizoctonia solani* in the US*******

If populations with high levels of resistance to a particular mode of action are widespread, avoid using solo products with that mode of action

If resistant isolates are detected in limited locations, adhere to resistance management guidelines

Resistance monitoring is recommended for blast and locally important pathogens in intensive use areas

References (to be completed)
*Minutes of FRAC GoI WG Meeting 2015, 2016 2017, 2018
**xx; Japan FRAC
***Japan FRAC
****Japan FRAC
***** Japan FRAC; xx
******xx
*******Minutes of FRAC GoI WG Meeting 2012

FRAC China

- New resistance requirements for registrations in China
  - Similar to EPPO 213
- This includes studies on resistance risk
  - MoA, mutagenesis experiments, resistance mechanism, cross-resistance, resistance factor, fitness studies, cross-resistance, inheritance, etc.
- Testing methods recommended
  - Six testing institutions in China
- Prescription on number of samples for sensitivity baselines
- Requirement to provide a resistance management strategy

Resistance Management

- FRAC initiated a study to better understand the impact of spray programs on resistance development
- Field protocols comparing strict vs block alternation
- Testing models:
  - CAA on grape downy mildew
  - QoI fungicides on grape powdery mildew
- Efficacy assessments
- Phenotyping and genotyping of pathogen populations before the season, mid-season and end-season
- Technically challenging…