Participants

The group is comprised of banana grower associations, institutions with activities in the areas of resistance research, monitoring or strategies and chemical manufacturers. The following delegates participated at the 2022 Banana Working Group Meeting:

Stefano Torriani	Syngenta (Chairman)
Lester Bermudez	Adama
Edgar Lazo	Adama
Javier Guillen (excused)	Adama
Gonzalo Enrique Donoso Cajas	Agrow, banaspray, incrops
Arturo Arcia	Banasan
Kelly Simoes	BASF
Ileana Arriola	BASF
Andrea Martin-Grand-Mazuir	BASF
Gabriela Jaramillo	BASF
Andreas Mehl	Bayer
Rolf Christian Becker	Bayer
Daniel Chamorro	Bayer
Harold Fersenth Leon	Bayer
Tarcisio Mosquera	Bonita
Rene Medina	Bonita
Sebastian Zapata Henao (excused)	Cenibanano
Douglas Marin	Ceradis
Luc De Lapeyre De Bellaire	Cirad
Nancy Chaves	Corbana
Alejandro Cedeno	Corteva
Rodolfo Ceciliano Solis	Del Monte
Victor Chique	Del Monte
Patricio Gutierrez Carvajal	Dole
Juan Jose Aycart	Dole
Juan Coward Morales (excused)	Eastman
Felicitos "Boy" Palis (excused)	Gowan
Hannah de Guzman (excused)	Gowan
Jairo Melgarejo	Gowan
Rebeca Madrigal Acuna	Monreri
Omar Corrales	Syngenta
Gilberto Olaya	Syngenta
Roberto Granja	Syngenta
Alexander Sibaja	UPL-ltd

Introduction

The FRAC Working Group is providing recommendations for fungicide resistance management strategies in banana cropping and aims to represent all major banana growing regions globally. The meetings of the Working Group are open (by agreement with the Chair) to parties with a serious interest in resistance management in banana. An important requirement for the membership and attendance at meetings is, as for any FRAC working group, active participation as the necessary precondition for productive discussions between the technical experts and the establishment of useful guidelines. This active participation usually consists of the sharing of technical data relating to fungicide resistance and resistance management. Any data sharing is undertaken in full compliance with anti-trust regulations.

Agenda of the Bi-Annual Meeting

1 General resistance management strategies in banana cropping

2 *Pseudocercospora fijiensis* (syn. *Mycosphaerella fijiensis*, black sigatoka)

2.1 Review of sensitivity status

- 2.1.1 Demethylation inhibitors (DMIs)
- 2.1.2 Amines
- 2.1.3 Qo inhibitors (QoIs)
- 2.1.4 Qi inhibitors (QiIs)
- 2.1.5 Anilinopyrimidines (APs)
- 2.1.6 Benzimidazoles (BCMs)
- 2.1.7 Toluamides
- 2.1.8 SDH inhibitors (SDHIs)
- 2.1.9 Guanidines
- 2.1.10 N-Phenylcarbamates

2.2 Review of guidelines

- 2.2.1 Demethylation inhibitors (DMIs)
- 2.2.2 Amines
- 2.2.3 Qo inhibitors (QoIs)
- 2.2.4 Qi inhibitors (QiIs)
- 2.2.5 Anilinopyrimidines (APs)
- 2.2.6 Benzimidazoles (BCMs)
- 2.2.7 Toluamides
- 2.2.8 SDH inhibitors (SDHIs)
- 2.2.9 Guanidines
- 2.2.10 N-Phenylcarbamates
- 2.2.11 Multi sites
- 2.2.12 Biologicals
- 2.2.13 Host Plant Defence Inducers

Minutes 2022 Meeting

The Minutes of the Banana FRAC Working Group Meeting in Miami / Florida, May 9th - May10th, 2022 are available in English.

Spanish Minutes will be published in the future.

Next meeting will be held in 2024 and chaired by Bayer.

<u>DISCLAIMER</u>:
In the following sections, recommendations are made on the use of chemical classes of fungicides with the goal to sustainably protect bananas from harmful fungi (black sigatoka and yellow sigatoka). Sustainable performance of fungicides can be achieved by careful resistance management to avoid a build-up of resistance by the fungi. Adherence to the recommendations is strictly voluntary. The recommendations apply to all products containing chemistry of the given Mode of Action class.

Listing of chemical classes or compounds in the following recommendations must not be interpreted as approval for use in a given country. Please check and respect the current registration status in your country of use and strictly adhere to the uses approved in your country.
The technical information contained in the global guidelines is provided to FRAC/CropLife International members, non-members, the scientific community and a broader public audience. While the FRAC Banana Working Group makes every effort to present accurate and reliable information in the guidelines, FRAC/CropLife International does not guarantee the accuracy, completeness, efficacy, timeliness, or correct sequencing of such information. FRAC/CropLife International assume no responsibility for consequences resulting from the use of the information herein, or in any respect for the content of such information, including but not limited to errors or omissions, the accuracy or reasonableness of factual or scientific assumptions, studies or conclusions. FRAC/CropLife International is not responsible for, and expressly disclaims all liability for, damages of any kind arising out of use, reference to, or reliance on information provided in the guidelines.

1 General Resistance Management Strategies in Banana

In general terms, the application of fungicides with different modes of action in mixtures (both ready-formulations and tank mixtures) and the alternation between non-cross-resistant fungicide classes are both suitable approaches to minimize the risk of resistance development. These use strategies are valuable for all site-specific fungicides and in situations when there is a need to cope with decreased sensitivity.

Another important tool in anti-resistance strategies is the restriction of the number of applications per year. A combination of limitation of spray applications, alternation and the use of mixtures will ensure efficient and sustainable disease control by using the maximum of tools available for resistance management. The use of efficient integrated disease management measures in parallel to fungicide spray programs, e.g., resistant varieties, biological control measures or cultural practices, will further decrease the selection pressure and thus resistance risk. If new fungicides become available in the future, amendments to these guidelines will be done accordingly if needed.

From the diseases, which affect banana cropping globally, black sigatoka (*Pseudocercospora fijiensis*, syn. *Mycosphaerella fijiensis*) is the most important and commercially relevant disease. Therefore, the following review of fungicide sensitivity and use recommendations are focussing on black sigatoka. The sensitivity status as described below refers to the changes between the last review in 2018 and the current situation.

First information on the sensitivity of yellow sigatoka, *Mycosphaerella musicola*, was presented at the 2014 meeting. No data were presented since then for this pathogen. This is related to a limited geographic relevance of this pathogen mainly in Australia.

2 *Pseudocercospora fijiensis* (syn. *Mycosphaerella fijiensis*)

2.1 Review of Sensitivity Status

At the start of the meeting, an antitrust reminder was presented.

During the meeting, data from Latin America, Africa, French West Indies and the Philippines were presented.

2.1.1 Demethylation inhibitors (DMIs)

The following DMI fungicides are used for black sigatoka control: difenoconazole, epoxiconazole, fenbuconazole, flutriafol, metconazole, propiconazole, tebuconazole, tetraconazole, triadimenol.

Shifting of DMI sensitivity over the baseline sensitivity has been observed up to 2009. Monitoring data presented over the past 13 years including results from 2019 to 2021 showed that sensitivity has stabilized in Ecuador, Colombia, Guatemala, Costa Rica, and Honduras with regional variability. In Philippines, stable and generally sensitive situation has been reported in the period between 2014 and 2020. In 2018, decreased sensitivity was observed in Belize, no data were presented for this country in 2022.

For the first time in 2016, monitoring results were presented for Dominican Republic, Martinique, Dominica, St. Lucia, Guadeloupe, Cameroon, and Ivory Coast. Additional information was presented in 2022 for Africa and French West Indies. Overall, the situation is as follows:

- clear sensitivity shift in the Dominican Republic (2016), Ghana (limited data from 2019), Cameroon (2019) and, to a lesser extent, in Ivory Coast (2019) with high variability
- in 2021, for the first time some strains showing a lower sensitivity were monitored from Martinique
- monitoring in 2016 showed sensitive populations in Dominica and St. Lucia, as well as in 2019 in Guadeloupe. No additional data were presented for Dominica and St. Lucia in 2022.

The performance of spray programs containing DMIs is good in all countries covered by this document, when used as part of an integrated disease management program and in accordance with the recommendations given in this document. When these recommendations are not followed, performance could be affected.

The mechanism of resistance to DMIs has been elucidated to be based on the overexpression of the *cyp*51 gene and additionally on mutations in the *cyp*51 gene of *P. fijiensis*, which can lead to incomplete cross-resistance. Further studies are required to confirm this hypothesis.

2.1.2 Amines

The following amine fungicides have been used in banana cropping: spiroxamine, fenpropimorph, fenpropidin, and tridemorph. Sensitivity data presented for the period 2019 to 2021 from Colombia, Costa Rica, Ecuador, Guatemala and Honduras confirmed that the situation remains highly sensitive and overall stable within the range of variability detected during the last 12 years.

2.1.3 Qo inhibitors (QoIs)

The following QoI fungicides are used in banana cropping: azoxystrobin, pyraclostrobin, trifloxystrobin.

Monitoring results from the last decade including data from 2019 to 2021 showed that overall frequency of resistance to QoIs was stable in Costa Rica, Ecuador, Guatemala, and Honduras with regional variability or even partly improved with no further spread in Philippines.

For the first time, monitoring results were presented in 2016 for Dominican Republic, Martinique, Dominica, St. Lucia, Guadeloupe, Cameroon, and Ivory Coast. Additional information was presented in 2022 for Africa and the French West Indies. Overall, the situation is as follows:

- widespread resistance in Dominican Republic (2016) and Cameroon (2019)
- resistance was detected at low levels in Ghana (2019) and Ivory Coast (2019)
- a single resistant strain was found for the first time in Martinique during 2020
- full sensitivity was reported in 2019 from Guadeloupe as in the past. Historic data presented in 2016 showed full sensitivity from Dominica and St. Lucia.

2.1.4 Qi inhibitors (QiIs)

The following QiI fungicide is used in banana cropping: fenpicoxamid.

Baseline data were presented in 2018.

2.1.5 Anilinopyrimidines (APs)

Pyrimethanil is the only active ingredient from the group of anilinopyrimidines, which is currently used in banana cropping.

For anilinopyrimidines, no sensitivity change was reported in the period from 2018 to 2021. The results presented from Colombia, Costa Rica, Ecuador, and Honduras showed a stable sensitivity as in the past.

2.1.6 Benzimidazoles (BCMs)

The following active ingredients of this group of fungicides can be used for black sigatoka control: benomyl, carbendazim, thiophanate, and thiophanate-methyl.

Resistance to benzimidazoles is widespread at high levels in Latin America. Field performance is affected in all banana regions with reported BCM-resistance.

For the first time in 2016 monitoring results were presented for Dominican Republic, Martinique, Dominica, St. Lucia, Guadeloupe, Cameroon, and Ivory Coast. Additional information was presented in 2022 for Africa. Overall, the situation is as follows:

- resistance to varying degrees in Ivory Coast (2019)
- resistance was detected at low levels in Ghana (2019) and Cameroon (2019)
- historic results showed full sensitivity in Martinique, Guadeloupe, Dominica, and St. Lucia. No data presented from these countries in 2022.

2.1.7 Toluamides

Zoxamide is the only active ingredient of this group of fungicides used for black sigatoka control. Sensitivity studies conducted until 2021 in Belize, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, and Philippines showed full sensitivity.

2.1.8 SDH inhibitors (SDHIs)

The following SDHI fungicides are used in banana cropping: boscalid, fluopyram, fluxapyroxad, and isopyrazam.
After establishing the baseline sensitivity, follow-up monitoring showed since 2012 occurrence of isolates with a reduced *in vitro* sensitivity, originating from Costa Rica and Ecuador. Since 2015 and 2017, also few adapted strains were observed in Colombia and Guatemala. Broad sensitivity was monitored in Honduras so far. Further studies are still ongoing to clarify the variability of sensitivity and the relevance for field use.

2.1.9 Guanidines

Baseline sensitivity data for dodine was presented for several countries in Latin America and Philippines in 2014.

Since 2016, additional data from Ecuador, Guatemala, Costa Rica, Belize, and Colombia still show sensitivity with a broad variation irrespective of the origin (no difference between wild areas and farms).

No data were presented in 2022 for the period from 2018 to 2021.

2.1.10 N-Phenylcarbamates

Since 2014, sensitive baseline- and follow-up monitoring data from the Philippines were presented for diethofencarb.

In 2018, baseline data from Latin America were presented.

No data were presented in 2022 for the period from 2018 to 2021.

2.2 Review of Guidelines

Some general statements apply to all fungicides used in bananas:

- For a mixture of non-cross-resistant partners to be effective in a resistance management strategy the rate of each component must be sufficient to provide satisfactory control when used alone at the same rate.
- The recommended label rate of each mixture component should be respected.
- Protectant (e.g., multi-site) fungicides are considered to be a very valuable and necessary tool for banana black sigatoka control programs and resistance management.
- Synchronisation of applications of fungicides from the same class can help in managing resistance.

Alternative applications methods: injection into the plant or ground localized application using fungicides at high risk of resistance (for example. DMI, QoI, SDHI) are considered to pose a risk to the efficacy of foliar applications because of the additional selection pressure. These technologies are likely to increase the resistance risk for any of the fungicides used.

2.2.1 Demethylation inhibitors (DMIs)

All the active ingredients belonging to the DMI class of fungicides are member of a single product group, amongst which there is in general some degree of cross-resistance. Mixtures of two or more DMIs can be applied to provide good biological efficacy; however, they must be considered as a solo DMI for resistance management.
The following guidelines are recommended for the use of DMI fungicides against black sigatoka in banana:

- DMIs should be used only in mixtures with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates.
- DMI fungicides are recommended to be used in alternation and full label rate with other, non-cross-resistant modes of action / product (if possible, with 2 cycles or more in between).
- Apply a maximum of 8 applications containing DMI fungicides, but not more than 50% of the total number of sprays.

- Applications containing DMI fungicides should preferably start at the onset of the annual disease progress curve.

2.2.2 Amines

Amine fungicides should be applied according to the following guidelines against black sigatoka in banana:

- Amine fungicides can be used solo or in mixtures, the application in mixtures is preferred.
- A maximum of 2 consecutive sprays (block) containing amine fungicides can be used. Alternation of amines with other, non-cross-resistant modes of action is preferred.
- Apply a maximum of 15 applications containing amine fungicides, but not more than 50% of the total number of sprays.

2.2.3 Qo inhibitors (QoIs)

For active ingredients belonging to the QoIs class of fungicides, the following use guidelines against black sigatoka are given:

- Apply QoI fungicides only in mixtures with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates for black sigatoka control.
- Apply QoI fungicides in alternation with other, non-cross-resistant modes of action. No consecutive QoI-applications should be applied.
- Apply a maximum of 3 applications containing QoI fungicides but not more than 33% of the total number of sprays. Applications containing QoI fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a QoI-free period.

2.2.4 Qi inhibitors (QiIs)

For active ingredients belonging to the QiIs class of fungicides, the following use guidelines against black sigatoka are given:

- Apply QiI fungicides only in mixtures with other, non-cross-resistant modes of action (preferably with multi-sites or compounds providing sufficient field performance), all partners at manufacturer's recommended effective rates for black sigatoka control.
- Apply QiI fungicides only in full alternation with other, non-cross-resistant modes of action. No consecutive QiI-applications should be applied.

- Apply a maximum of 3 applications containing QiI fungicides but not more than 33% of the total number of sprays. Applications containing QiI fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a QiI-free period.

2.2.5 Anilinopyrimidines (APs)

Anilinopyrimidine fungicides should be applied according to the following guidelines against black sigatoka in banana:

- AP fungicides should be applied only in mixtures with other, non-cross-resistant modes of action**,** all partners at manufacturer's recommended effective rates.
- AP fungicides should be used in alternation with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates. Consecutive or so-called "block" applications are not recommended.
- Apply a maximum of 8 applications containing AP fungicides but not more than 50% of the total number of sprays.

2.2.6 Benzimidazoles (BCMs)

Benzimidazole fungicides should be applied according to the following guidelines against black sigatoka in banana:

- Apply BCM fungicides only in mixtures with other, non-cross-resistant modes of action**,** all partners at manufacturer's recommended effective rates.
- BCM fungicides should be used in alternation with other, non-cross-resistant modes of action. No consecutive BCM-applications (blocks) should be applied.
- Apply a maximum of 3 applications containing BCM fungicides but not more than 33% of the total number of sprays.
- Applications containing BCM fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a BCM-free period.

2.2.7 Toluamides

Toluamide fungicides should be applied according to the following guidelines against black sigatoka in banana:

- Apply toluamide fungicides only in mixtures with other, non-cross-resistant modes of action**,** all partners at manufacturer's recommended effective rates.

- Toluamide fungicides should be used in alternation with other, non-cross-resistant modes of action (preferably with multi-site fungicides). No consecutive toluamide-applications (blocks) should be applied.
- Apply a maximum of 4 applications containing toluamide fungicides but not more than 33% of the total number of sprays.
- Applications containing toluamide fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a toluamide-free period.

2.2.8 SDH inhibitors (SDHIs)

SDHI fungicides should be applied according to the following guidelines against black sigatoka in banana:

- Apply SDHI fungicides only in mixtures with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates.
- SDHI fungicides should be used in alternation with other, non-cross-resistant modes of action. No consecutive SDHI-applications (blocks) should be applied.
- Apply a maximum of 3 applications containing SDHI fungicides but not more than 33% of the total number of sprays.
- Applications containing SDHI fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a SDHI-free period.

<u>Soil treatment of SDHIs for nematicidal use:</u>

- Where an SDHI is used as a soil drench for nematode control then, as a precautionary measure, it should be counted as one of the permitted SDHI applications.
- Soil and foliar applications should be preferably synchronized. If not applicable, use at least another mode of action (MoA) for the first foliar fungicide application providing satisfactory disease control against *P. fijiensis* within the first 7 days after the soil drench application.
- Continue foliar applications with alternating MoAs for the remaining growing period as stated above for the fungicidal application of SDHIs.

2.2.9 Guanidines

Guanidines should be applied according to the following guidelines against black sigatoka in banana:

- Apply guanidine fungicides only in mixtures with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates.
- Guanidines should be used in alternation with other, non-cross-resistant modes of action. No consecutive Guanidine-applications (blocks) should be applied.
- Apply a maximum of 6 applications containing Guanidine fungicides but not more than 33% of the total number of sprays.
- Applications containing Guanidine fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 6 weeks of a Guanidine-free period.

2.2.10 N-Phenylcarbamates

N-Phenylcarbamates fungicides should be applied according to the following guidelines against black sigatoka in banana:

- Apply N-Phenylcarbamates fungicides only in mixtures with other, non-cross-resistant modes of action, all partners at manufacturer's recommended effective rates.
- N-Phenylcarbamates fungicides should be used in alternation with other, non-cross-resistant modes of action. No consecutive N-Phenylcarbamates-applications (blocks) should be applied.
- Apply a maximum of 3 applications containing N-Phenylcarbamate fungicides but not more than 33% of the total number of sprays. Applications containing N-Phenylcarbamate fungicides should preferably start at the onset of the annual disease progress curve and be applied at times of lower disease pressure.
- Applications should be separated by at least 3 months of a N-Phenylcarbamate-free period.

2.2.11 Multi-sites

Multi-site fungicides (Mancozeb, Chlorothalonil, Propineb, Thiram, Metiram, and other fungicides of low resistance risk) can be applied for control of black sigatoka in the following way:

- Multi-site fungicides can be used solo or in mixtures with partners at manufacturer's recommended effective rates. There are no limitations or restriction concerning the number of applications, the timing, or the sequence as long as it is within the limits of the manufacturer's labels.

2.2.12 Biologicals

Biologicals with multiple modes of action belonging to FRAC BM01 and BM02 classes, based on *Bacillus amyloliquefaciens* (syn. *B*. *subtilis*) strains QST 713, FZB24, MBI600, and D747 (previously classified as F6); or extracts from *Melaleuca alternifolia* (previously classified as F7) and *Swinglea glutinosa* can be applied for control of black sigatoka in the following way

- Biologicals belonging to FRAC classes BM01 and BM02 can be used solo or in mixtures with partners at manufacturer's recommended effective rates. There are no limitations or restriction concerning the number of applications, the timing, or the sequence as long as it is within the limits of the manufacturer's labels.

2.2.13 Host Plant Defence Induction

Resistance to Plant Defence Inducers (PDIs) is generally very unlikely, as natural defence mechanisms being activated by such compounds in the host plant are not known to become inactive due to certain resistance mechanisms which have been yet described for systemic fungicides. The following active ingredient of the group of Plant Defence Inducers belonging to FRAC class P03 can be applied for disease control in banana: isotianil.

- Isotianil can be used solo or in mixtures with partners at manufacturer's recommended effective rates. Apply a maximum of 4 applications containing isotianil with a minimum time interval of 4 weeks, preferably one application every quarter of the year.

3 *Mycosphaerella musicola* (yellow sigatoka)

3.1 Review of Sensitivity Status

During the 2014 meeting data from Australia were presented, but no additional data during the 2016, 2018, and 2022 meetings.

3.1.1 Demethylation inhibitors (DMIs)

Sensitivity shifts have been confirmed for DMIs in Australia.

Field performance has been affected; however, the group remains generally effective.

3.1.2 Qo inhibitors (QoIs)

Resistance has been confirmed to be present in Australia (North Queensland). Field failures have been observed.

3.2 Guidelines

The same guidelines could be applied for *M. musicola* as outlined above for *P. fijiensis*.

4 Monitoring Methods

Monitoring methods have been published on the FRAC internet page.

4.1 Basic principles for resistance monitoring studies

All active ingredients with site-specific modes of action, which are used in the spray programme, should be included in the monitoring programme.

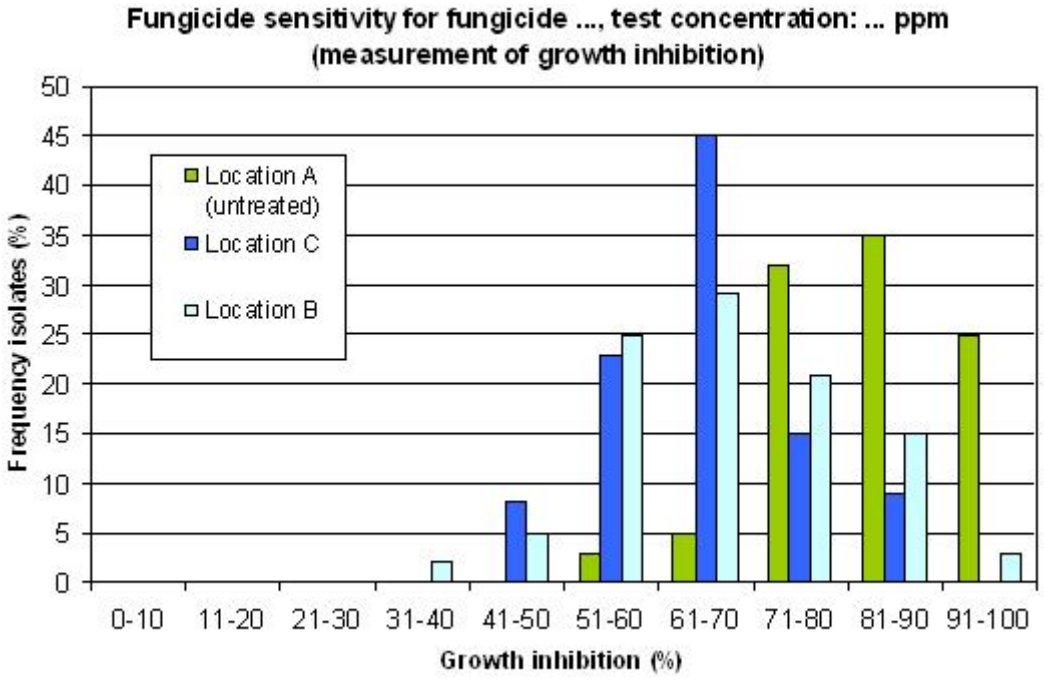
For field sampling, locations are preferred where the respective chemical class has been used intensively. Samples should be taken several times, minimum 2 times, per year. Wherever possible, field efficacy of spray programmes should be recorded at each sampling time.

For the definition of number and level of test concentrations, several factors have to be considered:

- Mode of action and type of resistance
  - Single site modes of action with disruptive type of resistance (Annex graph: Types of resistance) do not need testing of several concentrations. The use of the minimum inhibitory concentration (MIC = EC_{100}, i.e. the concentration at which 100% of a fully sensitive population is inhibited) for monitoring studies is sufficient to ensure that resistance can be reliably detected. Example: QoIs, BCMs.
  - Modes of action with shifting type of resistance (Annex graph: Types of resistance) need to be tested minimum at 2, but preferably at 4 to 5 different concentrations. In these cases, the concentration range should include the EC_{50} and EC_{95} values. Example: DMIs, Amines, SDHIs.
  - The doses recommended for Guanidine monitoring are: 0.01, 0.1, 1.0, 10 and 100.0 ppm. In order to ensure reliable results at least 1.0 and 10.0 ppm should be included.
  - For other MoA please refer to the FRAC monograph: www.frac.info.

- Sensitivity situation of the pathogen population in the monitoring region or country for shifting types of resistance (e.g., triazoles). Preliminary experiments might be needed to determine the correct monitoring concentrations.

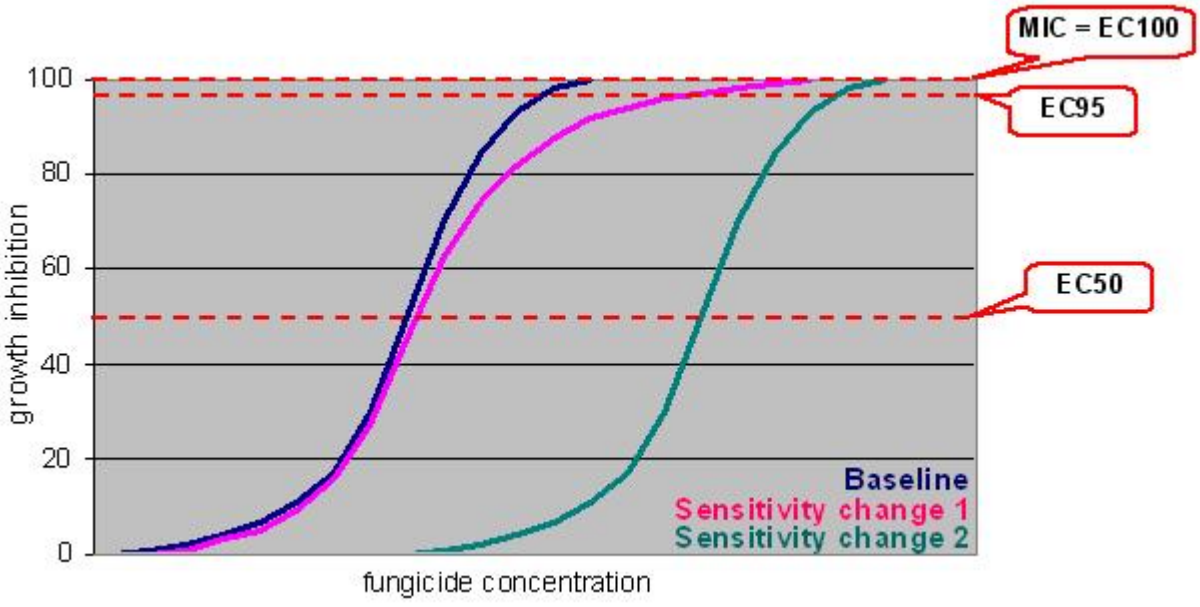
For the presentation of monitoring results, the following template can be used:



In this example the sensitivity distribution of three different locations is shown. The population from location A is the most sensitive, being followed by locations B and C with the lowest sensitivity, respectively. If resistant isolates are found unexpectedly in monitoring programs, the manufacturer should be contacted immediately.

4.2 Use of EC values for monitoring studies

The use of EC values for the interpretation of monitoring data is explained below. Sensitivity distribution curves and different EC values:



Summary for the use of different EC values according to the observed or expected changes in population sensitivity:

EC_{50}	Stable, less data variability	Shifting type of resistance
EC_{95}	Sensitive, small changes detectable Risk: false positive possible	
MIC or EC_{100}	Small changes difficult to detect	Disruptive type of resistance

4.3 Research projects

Detailed monitoring descriptions have been published in the monitoring folder of the FRAC internet page.

A research activity was identified which will improve the understanding of sensitivity monitoring data and practical resistance management strategies:

- The interpretation of monitoring data and correlation with the field efficacy of SDHI fungicides as well as for DMI fungicides due to recent findings as mentioned above.
- Results for *in vitro* sensitivity to crown rot pathogens with results from Costa Rica were presented for the first time.
- Alternative monitoring methods based on conidial germination have been published in the meantime and can be used as appropriate.

5 Summaries

5.1 Summary of FRAC guidelines for Banana

Updated during the FRAC working group meeting (Miami, Florida, USA, 9th May - 10th May 2022)

Chemical class	Solo or mixtures	Alternation or blocks	Maximum number of applications	Spray timing
Demethylation inhibitors (DMIs)	only in mixtures	only in full alternation	8 not more than 50% of total number of sprays	*
Amine fungicides	both, mixtures preferred	block of maximum 2 consecutive sprays, full alternation preferred	15 not more than 50% of total number of sprays	no restrictions within manufacturer's labels
Qo inhibitors (QoIs)	only in mixtures	only in full alternation	3 not more than 33% of total number of sprays	**
Qi inhibitors (QiIs)	only in mixtures	only in full alternation	3 not more than 33% of total number of sprays	**
Anilinopyrimidines (APs)	only in mixtures	only in full alternation	8 not more than 50% of total number of sprays	no restrictions within manufacturer's labels
Benzimidazoles (BCMs)	only in mixtures	only in full alternation	3 not more than 33% of total number of sprays	**
Toluamides	only in mixtures	only in full alternation	4 not more than 33% of total number of sprays	**
N-Phenylcarbamates	only in mixtures	only in full alternation	3 not more than 33% of total number of sprays	**
SDH inhibitors (SDHIs)	only in mixtures	only in full alternation	3 (including soil	**

			drench for nematode control, solo or in mixture) not more than 33% of total number of sprays	
Guanidines	only in mixtures	only in full alternation	6 not more than 33% of total number of sprays	***
Multi-sites	solo or mixtures	no restrictions within manufacturer's labels	no limits within manufacturer's labels	no restrictions within manufacturer's labels
Biologicals BM01 and BM02	solo or mixtures	no restrictions within manufacturer's labels	no limits within manufacturer's labels	no restrictions within manufacturer's labels
Plant Defence Inducers (PDI) FRAC P03	solo or mixtures		a maximum of 4 sprays	a minimum interval of 4 weeks between sprays

* Applications starting preferably at onset of annual disease progression curve

** Preferably at lower disease pressure; sprays must be separated by at least 3 months

*** Preferably at lower disease pressure; sprays must be separated by at least 6 weeks

5.2 Fungicide sensitivity for major chemical classes in banana cropping

Country	BCMs	DMIs	Amines	QoIs	QiIs	APs	SDHIs	Toluamides	Guanidines	N-Phenyl-carbamates
Belize	1	1	3	1	4	3	4	4	3	
Colombia	1	2	3	1	4	3	3	4	3	
Costa Rica	1	1	3	1	4	3	2	4	3	
Ecuador	1	2	3	2	4	3	3	4	3	
Guatemala	1	2	3	2	4	3	3	4	3	
Honduras	1	2	3	2	4	3	3*	4		
Panama	1	1	3	1	4	3	4			
Dominica	4	3		4						
Dominican R.	4	1		1						
Guadaloupe	4	3		4						
Martinique	4	3		3*						
St. Lucia	4	3		4						
Cameroon	2	1		1						
Ivory Coast	2	2		2						
Ghana	2	1*		2						
Philippines		3	3	2		3	4	4	3	3

4 no resistance detected (applicable only for QoIs, BCMs and SDHIs) * some hot spots only
3 high
2 medium
1 low

5.3 Product performance of major fungicide classes in banana cropping

Country	BCMs	DMIs	Amines	QoIs	QiIs	APs	SDHIs	Toluamides	Guanidines	N-Phenyl-carbamates
Belize	1	2	3	1	3	3	3	3	3	
Colombia	1	3	3	1	3	3	3	3	3	
Costa Rica	1	2	3	1	3	3	3	3		
Ecuador	1	3	3	2	3	3	3	3	3	
Guatemala	1	2	3	2	3	3	3	3	3	
Honduras	1	3	3	2	3	3	3	3	3	
Panama	1	2	3	1	3	3	3		3	
Philippines		3	3	2		3	3	3	3	3

3 high
2 medium
1 low

Information for Doninica, Dominican Republic, Ghana, Guadaloupe, Martinique
St. Lucia, Cameroon and Ivory Coast not included

6 Annex

6.1 Types of resistance