Banana
Working Group

FRAC
FUNGICIDE RESISTANCE
ACTION COMMITTEE

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 2012 Banana Working Group Meeting.

Karl-Heinz Lorenz (Chairman)	BASF
Denise Manker	AgraQuest, Inc
Juan Coward	Agriphar
Benny M. Corcolon	Anflocor-Tadeco
Julio Angulo	BASF
Eduardo Ceron	BASF
Hernan Vilchez	BASF
Silvia Bechara	BASF
Andreas Mehl	BCS
Harold Leon	BCS
Alvaro Segura	BCS
Rolf Christian Becker	BCS
Jose Manuel Dominguez	BCS
Tarsicio Mosquera Vidal	Bonita
Luz Edith Argel Roldan	Cenibanano
Mauricio Guzman Quesada	Corbana
Arturo Orozco	Del Monte
Ronny Mancilla	Del Monte
Juan Carlos Madrigal	Del Monte
José F. Rodriguez	Del Monte
Marco Vinicio Blanco	Dow AgroScience
Alex Kroneberg	FMC
Assaf Dotan	Makhteshim-Agan
Jorge Solis	Makhteshim-Agan
Lester Bermudez	Makhteshim-Agan
Rebeca Madrigal	Monreri
Peter Tirosh	Stockton
Ido Korman	Stockton
Marcial Guzman	Syngenta
Andy Leadbeater	Syngenta
Helge Sierotzki	Syngenta
Masanao Takaishi	Sumitomo

David Albert Lobo	Sumitomo
Marco Quiroz	Sumitomo
Alvaro Jimenez Abarca	Taminco
Eric Bureau	TOTAL Fluides
Diego Romero	TOTAL Fluides

The following people could not attend the meeting:

Greg Kemmitt	Dow AgroScience
Gert Kema	University Wageningen

Introduction

The FRAC Working Group is responsible 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.

Agenda of the Bi-Annual Meeting

1 General resistance management strategies in banana cropping

2 Review of sensitivity status

2.1 Demethylation inhibitors (DMIs)
2.2 Amines
2.3 Qo inhibitors (QoI)
2.4 Anilinopyrimidines (APs)
2.5 Benzimidazoles (BCMs)
2.6 SDHI fungicides
2.7 Guanidines
2.8 N-Phenylcarbamates

3 Review of guidelines

3.1 Demethylation inhibitors (DMIs)
3.2 Amines
3.3 Qo inhibitors (QoI)
3.4 Anilinopyrimidines (APs)
3.5 Benzimidazoles (BCMs)
3.6 SDHI fungicides
3.7 Guanidines
3.8 N-Phenylcarbamates

4 Monitoring methods

4.1 Basic principles for resistance monitoring studies
4.2 Use of EC values for monitoring studies
4.3 Research projects

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

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 number of applications per year. A combination of limitation of spray applications, alternation and the use of mixtures will ensure efficient and sustainable black sigatoka control by using the maximum of tools available for resistance management. The use of efficient integrated disease management measures in parallel to fungicide spray programmes, 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 (*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 exclusively. The sensitivity status as described below refers to the changes between the last review in 2010 and the current situation.

2 Review of Sensitivity Status

During the meeting data from Colombia, Costa Rica, Ecuador, Guatemala, and the Philippines were presented. No data from Africa, Brazil and other important banana growing countries were presented.

2.1 Demethylation inhibitors (DMIs)

The following DMI fungicides are used in banana cropping: bitertanol, difenoconazole, epoxiconazole, fenbuconazole, myclobutanil, propiconazole, tebuconazole, tetraconazole, triadimenol.

Shifting of DMI sensitivity over the baseline sensitivity has been observed until 2009 and has since been stabilized in Ecuador, Colombia, Guatemala, Costa Rica and the Philippines.

The performance of spray programmes containing DMI's is good in most countries, when used as part of an integrated disease management programme and in accordance with the recommendations given in this document.

2.2 Amines

The following amine fungicides are used in banana cropping: spiroxamine, fenpropimorph, fenpropidin and tridemorph. The sensitivity to amines is at high levels and did not change significantly during the last 2 years in all regions.

However, more monitoring information is required for Costa Rica to explain a few sensitivity fluctuations.

2.3 Qo inhibitors (QoI)

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

A further spread of resistance to QoIs was reported compared to 2010 in some farms in Northern parts of Ecuador. Resistance in Colombia was reported at medium to high level, although QoIs are not known to have been used in the last years. In Guatemala resistance was also observed. In Costa Rica QoI resistance is still very frequent.
In the Philippines QoI sensitivity is overall still high. In areas where reduced sensitivity was observed in the past and QoIs have not been used since 2003, the sensitivity improved.

2.4 Anilinopyrimidines (APs)

Pyrimethanil is the only active ingredient from the group of anilinopyrimidines, which is currently used in banana cropping.
For anilinopyrimidines a stable situation was further reported.

2.5 Benzimidazoles (BCMs)

The following active ingredients of this group of fungicides are used in banana cropping: benomyl, carbendazim, thiophanate, thiophanate-methyl. Resistance to benzimidazoles is widespread at high levels. Field performance is affected in all banana regions with reported BCM-resistance. Some reduction in resistance has been observed in Costa Rica.

2.6 SDHI fungicides

Baseline sensitivity data for boscalid, fluopyram and isopyrazam has been presented for several countries in Latin America.
All data show a high level of sensitivity irrespective of the origin (wild areas, farms).

2.7 Guanidines

Baseline sensitivity data for dodine has been presented for several countries in Latin America.

Data show a broad variation in sensitivity irrespective of the origin (wild areas, farms).

In Ecuador no change compared to baseline was found after 2 years of use.

2.8 N-Phenylcarbamates

No sensitivity data are available so far.

3 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 has to be respected.
- Protectant (multi-site) fungicides are considered to be a very valuable and necessary tool for the banana Sigatoka control programs and resistance management.
- Site-specific fungicides must be applied in oil or oil-water emulsions.
- Synchronisation of applications of fungicides from the same class can help managing resistance.

Alternative application methods: Stem injection with fungicides with medium to high resistance risk (e.g. DMI, QoI, SDHI) is considered to pose a risk to the efficacy of leaf applications due to additional selection pressure. This technology is thus likely to increase the resistance risk for any of the fungicides used.

3.1 Demethylation inhibitors (DMIs)

All the active ingredients belonging to the DMI class of fungicides are considered to be 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 do not provide an anti resistance strategy and must be treated 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 manufacturers' recommended effective rates.
- DMI fungicides are recommended to be used in full alternation with other, non-cross resistant modes of action.
- DMIs have to be used at a maximum of 8 applications, 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.

3.2 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. Full alternation of amines with other, non-cross resistant modes of action is preferred.
- Amines should be used at a maximum of 15 applications, but not more than 50% of the total number of sprays.

3.3 Qo inhibitors (QoI)

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 manufacturers' recommended effective rates.
- QoI fungicides have to be used in full alternation with other, non-cross resistant modes of action. No consecutive QoIs-applications can be applied.
- A maximum of 3 applications containing QoI fungicides or a maximum of 33% of the total number of sprays can be applied with QoIs.
- 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 have to be separated by at least 3 months of a QoI-free period.

3.4 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 manufacturers' recommended effective rates.
- AP fungicides have to be used in full alternation with other, non-cross resistant modes of action, all partners at manufacturers' recommended effective rates. Consecutive or so-called "block" applications are not recommended.
- A maximum of 8 applications containing AP fungicides or a maximum of 50% of the total number of sprays can be applied with APs.

3.5 Benzimidazoles (BCMs)

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

- BCM fungicides have to be applied only in mixtures.

- BCM fungicides have to be used in full alternation with other, non-cross resistant modes of action. No consecutive BCM-applications (blocks) can be applied.
- A maximum of 3 applications containing BCM fungicides or a maximum of 33% of the total number of sprays can be applied with BCMs.
- 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 have to be separated by at least 3 months of a BCM-free period.

3.6 SDHI fungicides

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

- SDHI fungicides have to be applied only in mixtures with other, non-cross resistant modes of action, all partners at manufacturers' recommended effective rates.
- SDHI fungicides have to be used in full alternation with other, non-cross resistant modes of action. No consecutive SDHI-applications (blocks) can be applied.
- A maximum of 4 applications containing SDHI fungicides and a maximum of 33% of the total number of sprays can be applied with SDHIs.
- 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 have to be separated by at least 8 weeks of a SDHI-free period.

3.7 Guanidines

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

- Guanidine fungicides can be used solo or in mixtures. The application in mixtures with other, non-cross resistant modes of action is preferred, all partners at manufacturers' recommended effective rates.
- Guanidines have to be used in full alternation with other, non-cross resistant modes of action. No consecutive Guanidine-applications (blocks) can be applied.
- A maximum of 6 applications containing Guanidine fungicides and a maximum of 33% of the total number of sprays can be applied with Guanidines.
- 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 have to be separated by at least 6 weeks of a Guanidine-free period.

3.8 N-Phenylcarbamates (New)

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

- N-Phenylcarbamates fungicides have to be applied only in mixtures with other, non-cross resistant modes of action, all partners at manufacturers' recommended effective rates.
- N-Phenylcarbamates fungicides have to be used in full alternation with other, non-cross resistant modes of action. No consecutive N-Phenylcarbamates-applications (blocks) can be applied.
- A maximum of 3 applications containing N-Phenylcarbamate fungicides or a maximum of 33% of the total number of sprays can be applied with N-Phenylcarbamates.
- 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 have to be separated by at least 3 months of an N-Phenylcarbamates - free period.

4 Monitoring Methods

Monitoring methods have been published on the FRAC internet page. Methods for N-SDHI, Guanidine and Phenylcarbamates fungicides will be published soon.

4.1 Basic principles for resistance monitoring studies

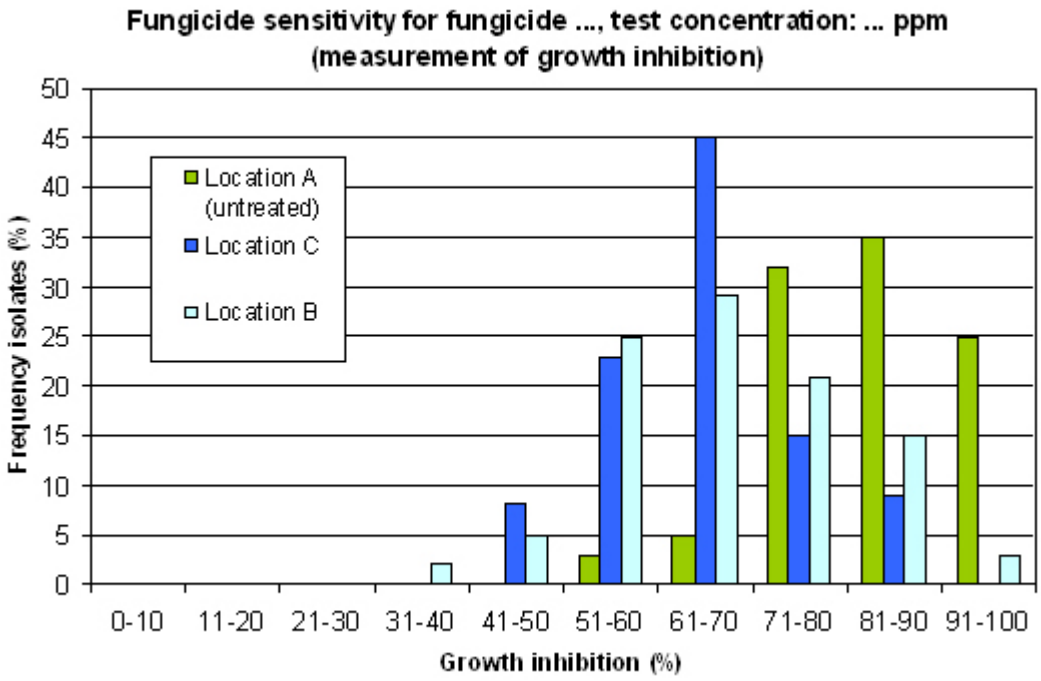
All active ingredients with site-specific modes of action, which are used in the spray programme, have to be included in the monitoring programme.

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 = EC100, 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: QoI, BCM.
  - 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 EC50 and EC95 values. Example: DMIs, Amines, SDHIs.
- 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.

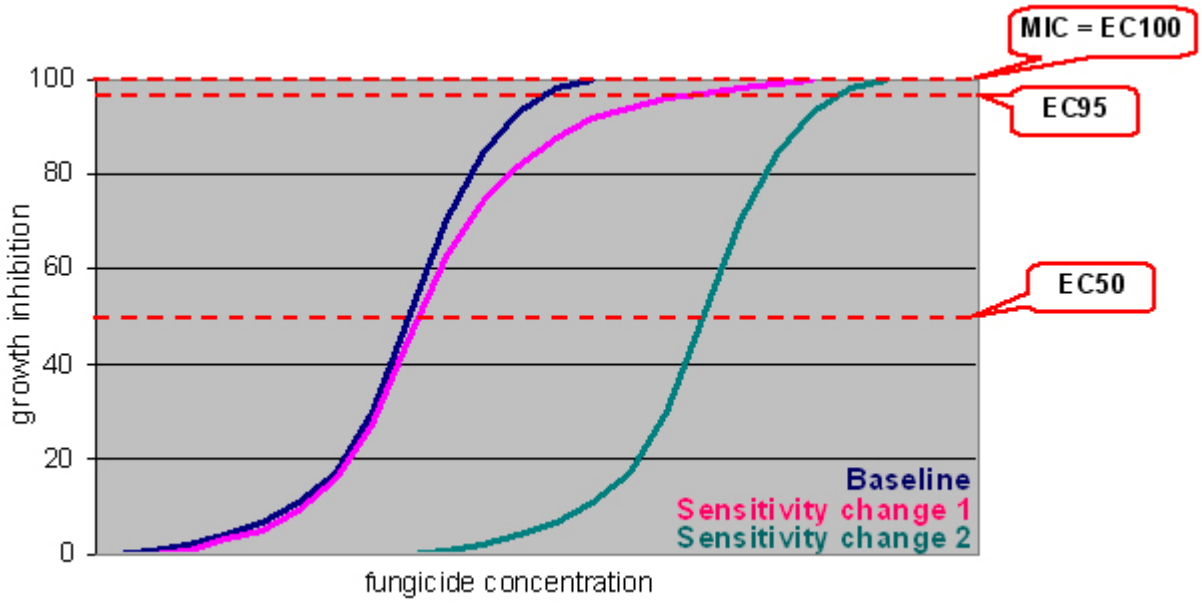
For the presentation of monitoring results, the following template can be used:



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 programmes, 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:

EC50	Stable, less data variability	Shifting type of resistance
EC95	Sensitive, small changes detectable Risk: false positive possible	
MIC or EC100	Small changes difficult to detect	Disruptive type of resistance

4.3 Research projects

Several research activities were identified which will improve the understanding of sensitivity monitoring data and practical resistance management strategies. For example, the interpretation of monitoring data and correlation with the field efficacy of respective products such as DMI fungicides. First greenhouse in planta results indicated a good correlation between decreasing *in vitro* sensitivity and decreasing disease control.

Observations on multiple resistance phenomena and fitness aspects should be further clarified.

5 Summaries

5.1 Summary of FRAC guidelines for Banana

Updated during the FRAC Working Group Meeting (Miami, Florida, USA, March 22-23, 2012)

Chemical class	Solo or mixtures	Alternation or blocks	Maximum number of applications	Spray timing
Demethylation inhibitors (DMI)	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
Qo inhibitors (QoI)	Only in mixtures	Only in full alternation	3 not more than 33% of total number of sprays	**
Anilinopyrimidines (AP)	Only in mixtures	Only in full alternation	8 not more than 50% of total number of sprays	No restrictions
Benzimidazoles (BCM)	Only in mixtures	Only in full alternation	3 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	**
SDHI fungicides	Only in mixtures	Only in full alternation	4 not more than 33% of total number of sprays	***
Guanidines	Both, mixtures preferred	Only in full alternation	6 not more than 33% of total number of 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 8 weeks
**** 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	BCM´s	DMI´s	Amines	QoI´s	AP´s
Costa Rica	1	1	3	1	3
Ecuador	1	2	3	2	3
Colombia	1	2	3	1	3
Guatemala	1	2	3	1	3
Panama	1	1	3	1	3
Honduras	1	2	3	2	3
Belize	1	2	3	2	3
Philippines		3	3	2*	3

4 no resistance detected (applicable only for QoI and BCM)
3 High
2 Medium * some hot spots only
1 Low

5.3 Product performance of major fungicide classes in banana cropping

country	BCM´s	DMI´s	Amines	QoI´s	AP´s
Costa Rica	1	2	3	1	3
Ecuador	1	3	3	2	3
Colombia	1	3	3	2	3
Guatemala	1	2	3	1	3
Panama	1	2	3	1	3
Honduras	1	2	3	2	3
Belize	1	2	3	2	3
Philippines		3	3	3	3

3 High
2 Medium
1 Low

6 Annex

6.1 Types of resistance