Membership

The working group is comprised of banana grower associations, institutions with activities in the areas of resistance research, monitoring or strategies and chemical manufacturers. The following members participated at the 2008 Banana Working Group Meeting.

Helge Sierotzki (Chair)	Syngenta
Denise Manker	AgraQuest, Inc
Laurent Cornette	Agriphar S.A.
Claro Arriola	BASF
Roger Fallas	BASF
Hernan Vilchez	BASF
Markus Frank	BASF
Klaus Kirsch	BCS AG, Marketing
Andreas Mehl	BCS AG, Research,
Harold Leon	BCS Andean countries
Alvaro Segura	BCS Central America
Tarsicio Mosquera Vidal	Bonita
Arturo Orozco	Del Monte
Jose F. Rodriguez	Del Monte
Marco Vinicio Blanco	Dow AgroScience
Herman Hidalgo	Dow AgroScience
Maria Emilia Rita G. Fabregar	Lapanday
Assaf Dotan	Makhteshim-Agan
Ricardo Astua	Monreri
Luis Jacome	Pathotec
Marcial Guzman	Syngenta
Andy Leadbeater	Syngenta
Gilberto Olaya	Syngenta
Benny M.Corcolon	Tagum Agricultural
Jean-Michel Denis	Taminco

The following members could not attend the meeting:

Friedhelm Gauhl	Chiquita
Mauricio Guzman Quesada	Corbana
Juan Carlos Madrigal	Del Monte
Brian Sheppard	Dow AgroScience
Alex Kroneberg	FMC
Rodrigo Blanco	Banana Growers Association
Alex Martinez	Banana Growers Association
Hubert Masses	Taminco NV
Gregorio Leandro	Dole

Introduction

The working group is responsible for fungicide resistance strategies in banana cropping and aims to represent all major banana growing regions globally. The working group is open to parties with a serious interest in resistance management in banana. An important requirement for the membership is – as for any FRAC working group – active participation as necessary precondition for productive discussions between the technical experts and the establishment of useful guidelines.

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)

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)

4 Monitoring methods
4.1 Basic principles for resistance monitoring studies
4.2 Use of EC values for monitoring studies
4.3 Research projects
4.4 Demethylation inhibitors (DMIs)
4.5 Amines
4.6 Qo inhibitors (QoI)
4.7 Anilinopyrimidines (APs)
4.8 Benzimidazoles (BCMs)

Sections 4.4 to 4.8 to be replaced by detailed monitoring descriptions included in the monitoring folder of the FRAC internet page

5 Summaries
5.1 FRAC Guidelines for Banana in 2008
5.2 Fungicide sensitivity for major chemical classes in banana cropping
5.3 Product performance of major fungicide classes in banana cropping

6 Annex
6.1. Types of Resistance

Minutes 2008 Meeting

The Minutes of the Banana FRAC Working Group Meeting in Orlando / Florida, February 6-7, 2008 are available in English and Spanish.

2008 Minutes English

Resumen de la Reunión 2008
Sensibilidad a los fungicidas
Resumen de guias 2008

Next meeting will be hold in 2010 and chaired by Bayer Crop Science.

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 hygienic and 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 2006 and the current situation.

2. Review of Sensitivity Status

During the meeting no data from Africa were presented.

2.1 Demethylation inhibitors (DMIs)

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

Shifting of DMI sensitivity over the baseline sensitivity has been observed in 2007 and the reported levels were low in Ecuador, moderate in Colombia and Southern parts of Guatemala and high in Costa Rica and Northern parts of Guatemala. No change was reported from Honduras. No data were reported from Panama.

There was a slight shift in sensitivity in the Philippines.

The performance of spray programmes containing DMI's is good, 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 and tridemorph. The sensitivity to amines is at high levels and did not change significantly during the last 2 years in all regions.

2.3 Qo inhibitors (QoI)

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

Resistance to QoIs was detected for the first time at low frequency in some farms in Northern of part of Ecuador. Belize has discontinued the use of QoI's after first detection of resistance in 2006. In the regions Santa Marta and Uraba of Colombia wide spread resistance was reported. In Guatemala resistance was observed only in the Northern regions of the country. In Costa Rica QoI resistance is still frequent.

In the Philippines no new data are available for the QoI-resistance situation.

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 reported.

2.5 Benzimidazoles (BCMs)

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

3. Review of Guidelines

Some general statements apply to all fungicides used in bananas:

- For a mixture 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 must 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.

Alternative application methods: Stem injection with fungicides with medium to high resistance risk (e.g. DMI, QoI) 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 (new)** with other, non-cross resistant modes of action, all partners at rates recommended by manufacturer.
- ❖ 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, all partners at recommended effective manufacturer's rates.
- ❖ 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 recommended effective manufacturer's 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.
- Apply QoI fungicides preferably at the onset of the annual disease progress curve and should 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 can be used solo or in mixtures; application in mixtures is preferred.
- AP fungicides have to be used in full alternation with other, non-cross resistant modes of action, all partners at recommended effective manufacturer's rates. Consecutive or so-called "block" applications are not recommended.
- A maximum of 6 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.

4. Monitoring Methods

Monitoring methods will be collected from members of the Banana FRAC working group and deposited on the FRAC internet page. The collected methods will then replace the sections 4.4 to 4.8.

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

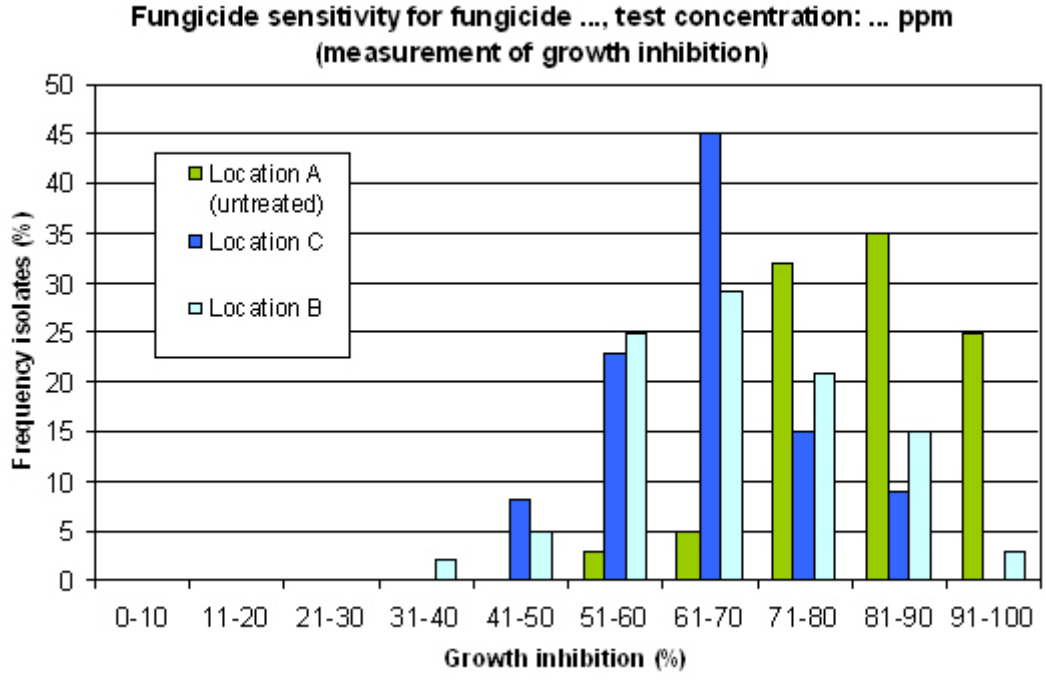
- Single site modes of action with disruptive type of resistance (see Annex) do not need testing of several concentrations. The use of the minimum inhibitory concentration (MIC = EC100, i.e. the concentration at which 100% of a fully sensitive population is inhibited) for monitoring studies is sufficient 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.

Sensitivity situation of pathogen

With the shifting type of resistance (e.g. triazoles), it is important to determine the sensitivity situation of the population in the region or country prior to the start of the monitoring program. Preliminary experiments may be needed to determine the correct monitoring concentrations.

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

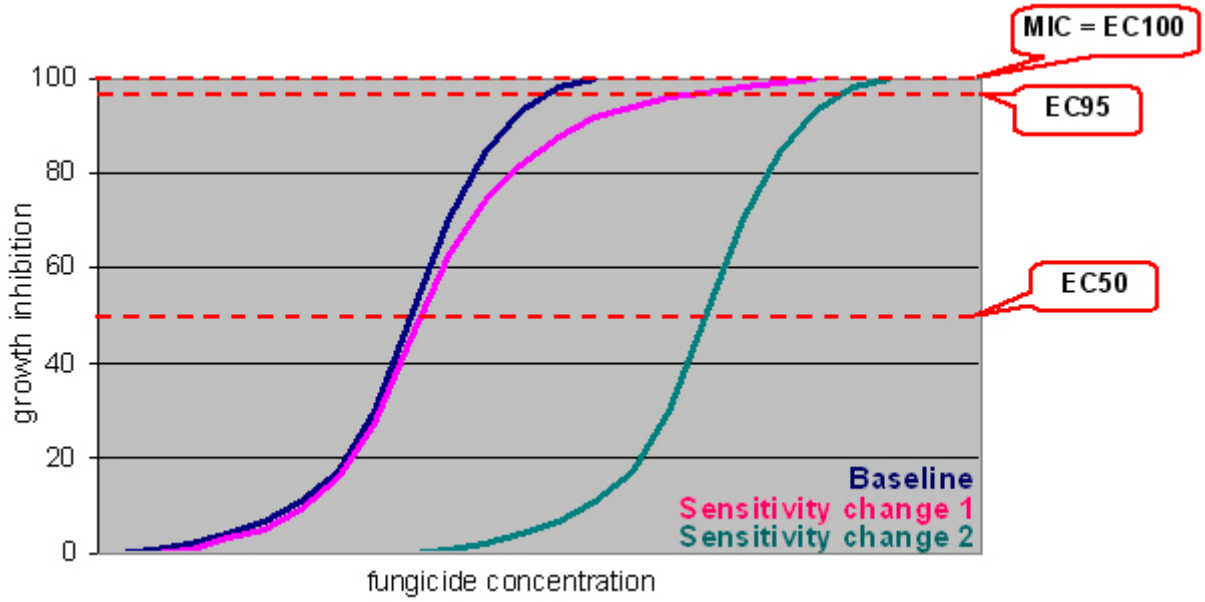


In this example the sensitivity distribution of three different locations is shown. The population from location A is the most sensitive, followed by locations B and C with the lowest sensitivities, respectively. If resistant isolates are found unexpectedly in monitoring programmes, the manufacturer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

EC 50	Stable, less data variability	Shifting type of resistance
EC 95	Sensitive, small changes detectable Risk: false positive possible	
MIC or EC100	Small changes difficult to detect	Disruptive type of resistance

4.3 Research projects

One major research activity was identified which will improve the understanding of sensitivity monitoring data and practical resistance management strategies.

<u>Interpretation of monitoring data and correlation with the field efficacy</u>
Focussing on Qo inhibitors (strobilurins) a greenhouse trial programme is planned. The objective of this work is to establish a correlation between resistance levels in the field and the efficacy of the affected chemical class. Ricardo Astua (Monreri) agreed to coordinate the activities.

4.4 Demethylation inhibitors (DMIs) (to be replaced by method descriptions)

The recommended DMI concentrations for monitoring studies depend greatly on the sensitivity situation in the respective region. Especially the highest tested concentration has to be adjusted to the shifting status of the monitored region. It is recommended to test at least two concentrations in monitoring studies.

Approximate concentrations for sensitivity monitoring are as follows:

Shifted populations:

0 (untreated check) - 0.03 - 0.1 - 0.3 -1.0 and 3.0 ppm

Populations with high sensitivity, i.e. without strong shift or with sensitivity close to the baseline population:

0 (untreated check) - 0.003 -0.01 - 0.1 and 1.0 ppm

In regions where the sensitivity level is expected to have decreased, it is recommended to include 3 ppm. An effort will be made to establish recommended testing concentrations for studies including only one or two concentrations (coordinator: T. Arroyo). Since there is a valuable long history database available for propiconazole, the continuation of monitoring studies with this fungicide is recommended.

4.5 Amines (to be replaced by method descriptions)

The doses recommended for tridemorph and spiroxamine are as follows:

0 (untreated check) - 0.1 - 0.3 - 1.0 and 10ppm

At least 2 concentrations should be used for monitoring studies. Recommendations, which concentrations should be used, will be provided by the technical expert team.

4.6 Qo inhibitors (QoI) (to be replaced by method descriptions)

A research study has been carried out (Syngenta; unpublished) to clarify the role of alternative oxidase and give recommendations for monitoring studies.

According to the presented results, there is a risk for false-positive detection of QoI-resistance in *M. fijiensis*, esp. when obtained with lower test concentrations. In order to ensure reliable results in monitoring studies, the following recommendations are given:

- For the monitoring tests for all active ingredients (azoxystrobin, pyraclostrobin and trifloxystrobin) discriminatory concentration equal or as similar as possible to the minimum inhibitory concentrations (MIC) should be used, i.e. not below 10 ppm.
- In germ tube elongation studies a germ tube length of longer than 150 mm indicates resistance to QoI, based on the mutation leading to G143A.

- Especially in regions with first detection of QoI-resistance confirmatory tests would be needed to exclude false-positives. The use of SHAM does increase the reliability of monitoring studies due to its efficacy in blocking the alternative pathway via alternative oxidase. If SHAM is used, a concentration of 50 µM in comparison to SHAM free plates is recommended.
- In addition to the recommendations above, the following general recommendations should be followed:
- A minimum of 150 and preferably 300 ascospores should be assessed. The measurement of 300 ascospores gives a 95% probability of being able to detect 1% resistant spores.
- In order to confirm QoI-resistance for isolates with germ tube length higher than 150 µm: the germinated ascospore is transferred to new medium at the same fungicide concentration. Alternatively, pure isolates can be obtained and consecutively conidia are tested for sensitivity. In case further growth is observed, QoI-resistance is confirmed.

4.7 Anilinopyrimidines (APs) (to be replaced by method descriptions)

The following concentrations are recommended for pyrimethanil monitoring:

0 (untreated check) – 1 – 3 – 10 – 30 and 100 ppm.

At least 2 concentrations should be used for monitoring studies. Recommendations, which concentrations should be used, will be provided by the technical expert team.

4.8 Benzimidazoles (BCMs) (to be replaced by method descriptions)

For monitoring of BCM fungicides a discriminatory concentration equal or as close as possible to the minimum inhibitory concentrations (MIC) should be used for monitoring studies.

Accordingly the following concentration(s) are recommended:

0 (untreated check) – 1 – 5 and 10 ppm.

5. Summaries

5.1 Summary of FRAC guidelines for Banana 2006

Updated during the FRAC working group meeting (Orlando, Florida, USA, 6-7. Feb. 2008)

Chemical class	Solo or mixtures	Alternation or blocks	Maximum number of applications	Spray timing
Demethylation inhibitors (DMI)	Only in mixtures **(new)**	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)	Both, mixtures preferred	Only in full alternation	6; 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	**

* Applications starting preferably at onset of annual disease progression curve

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

5.2 Fungicide sensitivity of 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	atlantic coast; pacific coast	3
Panama	1	1	3	1	3
Honduras	1	3	3	4	3
Belize	1	3	3	2	3
Philippines	2	3	3	2	3

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

5.3 Field 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	3	3
Colombia	1	3	3	2	3
Guatemala	1	3	3	atlantic coast; pacific coast	3
Panama	1	2	3	1	3
Honduras	1	3	3	3	3
Belize	1	3	3	3	3
Philippines	2	3	3	2	3

3 High
2 Medium
1 Low

6. Annex

6.1 Types of resistance