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 2014 Banana Working Group Meeting.

Helge Sierotzki	Syngenta
Juan Coward	Agriphar S.A.
Maria Isabel Jimenez	AGROLAB - Ecuador
Benny M. Corcolon	Anflocor-Tadeco
Julio Angulo	BASF
Karl-Heinz Lorenz	BASF
Andreas Mehl	Bayer CropScience
Rolf Christian Becker	Bayer CropScience
Tarsicio Mosquera Vidal	Bonita
Luz Edith Argel Roldán	CENIBANANO
Gabriela Jaramillo	CIB - Colombia
Arturo Orozco	Del Monte
Roberto Valenciano	Del Monte
Ronny Mancilla	Del Monte
Noel Perpetua	Dole
Marco Vinicio Blanco	Dow AgroScience
Doug Wilson	FRMRG Australia
Lester Bermudez	Makhteshim-Agan
Roger Martinez	Makhteshim-Agan
Rebeca Madrigal	Monreri
David Albert Lobo	Sumitomo Chemical Co., Ltd.
Felipe Madriz	Sumitomo Chemical Co., Ltd.
Marco Quiroz	Sumitomo Chemical Co., Ltd.
Masanao Takaishi	Sumitomo Chemical Co., Ltd.
Andy Leadbeater	Syngenta
Marcial Guzman	Syngenta
Pablo Chong	Uni Wageningen

The following organisations were not represented at the meeting:

Chiquita, Corbana, CARBAP, FRAC-Brasil, Stockton

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 *Mycosphaerella fijiensis* (black sigatoka)

2 Review of sensitivity status

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

3 Review of guidelines

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

4 *Mycosphaerella musicola* (yellow sigatoka)

4 Review of sensitivity status and guidelines
4.1 Demethylation inhibitors (DMIs)
4.2 Qo inhibitors (QoIs)
4.3 Guidelines

5 Monitoring methods

5.1 Basic principles for resistance monitoring studies
5.2 Use of EC values for monitoring studies
5.3 Research projects

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

6 Summaries

6.1 FRAC Guidelines for Banana in 2014
6.2 Fungicide sensitivity for major chemical classes in banana cropping
6.3 Product performance of major fungicide classes in banana cropping

7 Annex

7.1 Types of Resistance

Minutes 2014 Meeting

The Minutes of the Banana FRAC Working Group Meeting in Miami / Florida, February 4-5, 2014 are available in English, French and Spanish.

2014 Minutes English

 hyperlink to pdf file inserted as soon as minutes agreed

2014 …

 …Will follow shortly

Minutas de la reunion 2014 sensibilidad de los fungicidas
Resumen de guias 2014

 el hyperlink al archivo del pdf insertó tan pronto como los minutos convinieran Will follow shortly

Next meeting will be held in 2016 and chaired by Bayer CropScience.

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 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. The sensitivity status as described below refers to the changes between the last review in 2012 and the current situation.

First information on the sensitivity of yellow sigatoka, *Mycosphaerella musicola*, was presented at the meeting.

2 Review of Sensitivity Status

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

During the meeting, data from Latin America and the Philippines were presented. No data from Africa, Brazil and other important banana growing countries were presented.

2 *Mycosphaerella fijiensis*

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 up to 2009. Sensitivity has since stabilized at a higher level compared to pre 2009 in Belize, Ecuador, Colombia, Guatemala, Costa Rica, Honduras, Panama and the Philippines.

The performance of spray programmes containing DMIs is good in all countries covered by this document, when used as part of an integrated disease management programme and in accordance with the recommendations given in this document.

Mechanism of resistance to DMIs has been elucidated to be based on mutations in the cyp 51 gene of *M. fijiensis*. Additional reduction of sensitivity may come from overexpression of the cyp 51 gene.

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 4 years in all regions.

2.3 Qo inhibitors (QoIs)

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

Frequency of resistance to QoIs was reported to be stable with no further spread observed in all countries.

In areas where reduced sensitivity was observed in the past and QoIs have not been used since 2003, the sensitivity improved e. g. in Guatemala and the Philippines.

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)

No data was presented in the 2014 meeting.

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.

2.6 SDHI fungicides

The following SDHI fungicides are used in banana cropping: boscalid, fluopyram, fluxapyroxad and isopyrazam.
After establishing the baseline sensitivity, follow-up monitoring showed for the first time isolates with a reduced *in vitro* sensitivity, originating from Costa Rica and Ecuador. Further studies are ongoing to clarify the variability of sensitivity and the relevance for field use.

2.7 Guanidines

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

Data show sensitivity with a broad variation irrespective of the origin (no difference between wild areas and farms).

2.8 N-Phenylcarbamates

Sensitive baseline data were presented from the Philippines.

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 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.

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.
- 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.

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.
- Apply a maximum of 15 applications containing amine fungicides, but not more than 50% of the total number of sprays.

3.3 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 manufacturers' recommended effective rates for black sigatoka control.
- Apply QoI fungicides in full 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.

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 should 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.

Apply a maximum of 8 applications containing AP fungicides but not more than 50% of the total number of sprays.

3.5 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 manufacturers' recommended effective rates.

- BCM fungicides should be used in full 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.

3.6 SDHI fungicides

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 manufacturers' recommended effective rates.
- SDHI fungicides should be used in full 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
- Use another MoA for the first foliar fungicide application providing satisfactory disease control against *M. 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

3.7 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 manufacturers' recommended effective rates.

- Guanidines should to be used in full 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.

3.8 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 manufacturers' recommended effective rates.
- N-Phenylcarbamates fungicides should be used in full 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-Phenylcarbamates - free period.

3.9 Multi sites

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

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

4 *Mycosphaerella musicola* (yellow sigatoka)

4 Review of Sensitivity Status

During the meeting data from Australia were presented.

4.1. Demethylation inhibitors (DMIs)

Sensitivity shifts have been confirmed for DMIs in Australia.

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

4.2. Qo inhibitors (QoIs)

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

4.3 Guidelines

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

5 Monitoring Methods

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

5.1 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:

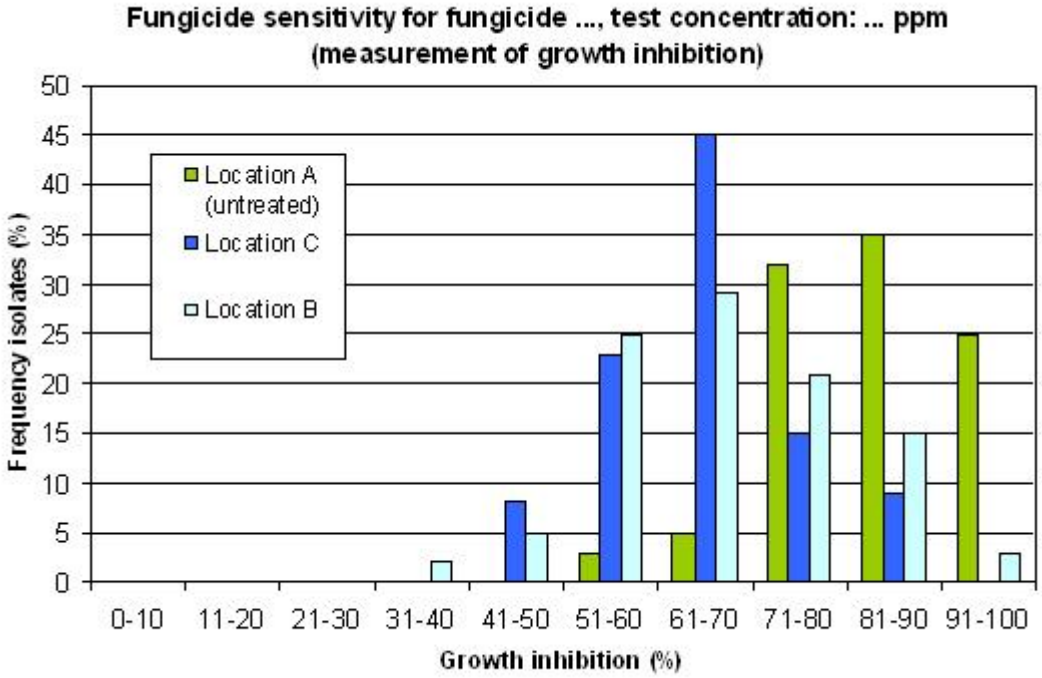
- Mode of action and type of resistance
  - Single site modes of action with disruptive type of resistance (Annex graph: Types of resistance) do not need testing of several concentrations. The use of the minimum inhibitory concentration (MIC = EC100, i.e. the concentration at which 100% of a fully sensitive 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.

- 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

- 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:

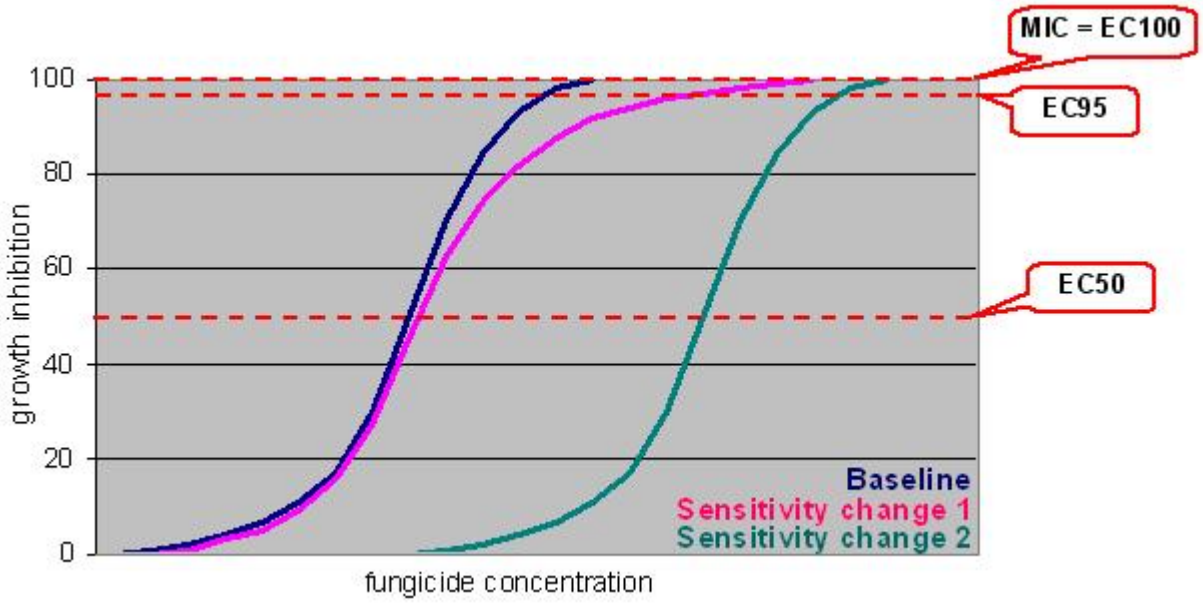


In this example the sensitivity distribution of three different locations is shown. The population from location A is the most sensitive, being followed by locations B and C with the lowest sensitivity, respectively. If resistant isolates are found unexpectedly in monitoring programmes, the manufacturer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

5.2 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

5.3 Research projects

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.

5 Summaries

6.1 Summary of FRAC guidelines for Banana

Updated during the FRAC working group meeting (Miami, Florida, USA, 4-5 Feb, 2014)

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 within manufacturer's labels
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 within manufacturer's labels
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	3 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 restriction within manufacturer's labels	No limits within manufacturer's labels	No restrictions within manufacturer's labels

* 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

6.2 Fungicide sensitivity for major chemical classes in banana cropping

country	BCM's	DMI's	Amines	QoI's	AP's	SDHI	Guanidines	N-Phenylcarbamates
Costa Rica	1	1	3	1	3	2	3	
Ecuador	1	2	3	2	3	3*	3	
Colombia	1	2	3	1	3	4	3	
Guatemala	1	2	3	1	3	4	3	
Panama	1	1	3	1	3	4		
Honduras	1	2	3	2	3	4	3	
Belize	1	2	3	2	3	4	3	
Philippines		3	3	2*	3	4	3	3

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

* some hot spots only

6.3 Product performance of major fungicide classes in banana cropping

country	BCM's	DMI's	Amines	QoI's	AP's	SDHI	Guanidines	N-Phenylcarbamates
Costa Rica	1	2	3	1	3	3		
Ecuador	1	3	3	2	3	3	3	
Colombia	1	3	3	1	3	3	3	
Guatemala	1	2	3	1	3	3	3	
Panama	1	2	3	1	3	3	3	
Honduras	1	2	3	2	3	3		
Belize	1	2	3	2	3	3	3	
Philippines		3	3	2	3	3	3	3

3 High
2 Medium
1 Low

7 Annex

7.1 Types of resistance