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REPORT
on
CARIBBEAN BLACK SIGATOKA
MANAGEMENT WORKSHOP

Kingston, Jamaica
October 2-5, 2001

IICA OFFICE IN SAINT LUCIA

WHAT IS IICA?

The Inter American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture in the Inter American system.

As a hemispheric technical cooperation agency, IICA can be flexible and creative in responding to needs for technical cooperation in countries, through its thirty four Technical Cooperation Agencies, its five Regional Centers and Headquarters, which coordinate the implementation of strategies tailored to the needs of each Region.

The 1998 - 2002 Medium Term Plan (MTP) provides the strategic framework for orienting IICA's actions during this four- year period. Its general objective is to support the efforts of the Member States in achieving sustainable agricultural development, within the framework of hemispheric integration and as a contribution to human development in rural areas.

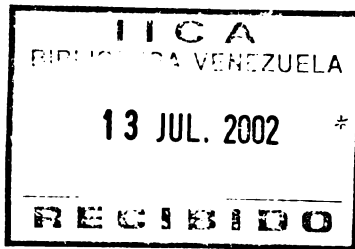
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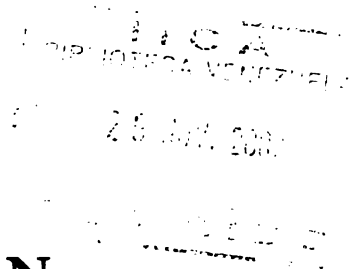
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**CARIBBEAN
BLACK SIGATOKA
MANAGEMENT WORKSHOP**

Kingston, Jamaica
October 2-5, 2001

Organized by:

The Inter American Institute for Cooperation on Agriculture (IICA)
Banana Export Company (BECO)
EU Banana Support Programme (EUBSP)

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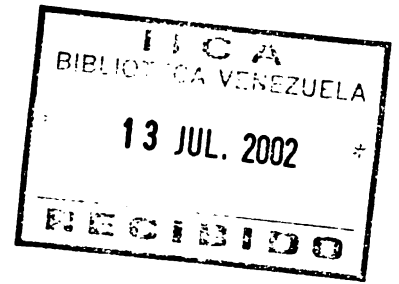
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The successful implementation of this workshop was due to the effective collaboration among several partner organizations and the generous and efficient input of many individuals. Due appreciation and gratitude are extended to the Government and people of Jamaica, for their support and cooperation, which was a critical factor in hosting this workshop and for the successful execution of the practical sessions.

The effective networking and participation of private and public sector institutions involved in agriculture across the Caribbean Region, especially those involved in banana production, is also recognized and appreciated as a key element in achieving the goals of this workshop. In this regard sincere appreciation is extended to all the workshop participants, individuals, organizations and Caribbean member countries.

The technical cooperation amongst IICA, BECO and the EUBSP in Jamaica effectively demonstrated during this workshop through their generous sponsorship and information sharing. The technical information presented during this workshop is of outstanding quality and will undoubtedly serve as a useful reference to the process of prevention and control of Black Sigatoka disease in the Caribbean area. The distinguished contributions of Dr. Janet Conie and her team of researchers from the BECO, Research Department were critical to the success of the workshop, they are highly commended for their readiness and openness in sharing their experiences with their regional colleagues.

The logistical support of Mr. Bryon Noble, the IICA Jamaica Team, Dr. Janet Conie and Ms Marina Young is greatly acknowledged. The Secretarial support provided by Ms Andrea Marquis is also duly acknowledged.



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FORWARD

The Banana and Plantain Leafspot disease caused by the fungus *Mycosphaerella fijiensis* is considered to be the most serious disease of the banana plant family. Outbreaks of black Sigatoka leads to death of leaves, pre mature fruit ripening, poor fruit quality and loss of gross harvest yield. These effects reduce the income of farmers, the export and domestic industries and jeopardize the sustainability of the banana trade.

Since reported in the Caribbean, on the island of Cuba in 1992, this destructive leaf disease has slowly spread to other Caribbean islands, including Jamaica and the Dominican Republic in 1997 and the Republic of Haiti in 2000, posing an even more serious threat to the banana industry than its predecessor yellow Sigatoka (*Mycosphaerella musicola*).

Black Sigatoka is the more aggressive of the two diseases and has the potential to virtually replace Yellow Sigatoka (*Mycosphaerella musicola*). Its appearance in the various countries has resulted in a significant increase in the cost of control.

Given the significant economic implications of the disease in terms of both cost of disease control and revenue loss, it was necessary for Caribbean countries to begin a collaborative process aimed at preventing the introduction of or minimizing its impact in other parts of the region.

IICA in collaboration with the Jamaica Banana Export Company (BECO), through this workshop made it possible for the Jamaican experience to be shared with its Caribbean neighbours. Jamaica's researchers through support from the European Union Banana Support Programme (EUBSP) have developed an efficient and effective national programme for black Sigatoka control. The workshop therefore, provided an opportunity for information sharing, particularly with regard to the relevant components of the Jamaica National Programme as well as provides hands-on experience in the technical aspects of disease identification, monitoring and management.

∕ This report is a compilation of the technical papers presented at the workshop to address disease epidemiology, etiology and management strategies for disease monitoring and control. The report is therefore intended to serve as resource material for both participants and non-participants in their endeavours at establishing national programmes for black Sigatoka control.

LIST OF ACRONYMS / ABBREVIATIONS

ACP	African, Caribbean and Pacific countries
BECO	Banana Export Company
BSV	Banana Streak Virus
BTC	Banana Trading Company
CABI	Centre for Agricultural Biosciences International
CAPS	Cleaved Amplified Polymorphic Sequences
CATIE	Tropical Agriculture Research and Training Centre
CIRAD	Centre de Coopéracion Internationale en Reserche Agronomique pour le Developpément
CORBANA	Corporation Bananera Nacional, (Costa Rica)
DBMC	Dominican Banana Marketing Corporation
DMU	Disease Management Unit
EU	European Union
EUBSP	European Union Banana Support Programme
FAO	Food and Agriculture Organization of the United Nations
FHIA	Fundacion Hondureña de Investigacion Agricola (Honduras)
FRAC	Fungicide Resistance Committee
FSM	Fungicide Sensitivity Monitoring
GPS	Geographic Positioning Systems
IICA	Inter American Institute for Cooperation on Agriculture
IITA	International Institute for Tropical Agriculture
INIBAP	International Network for the Improvement of Bananas and Plantains
MTP	Medium Term Plan
OAS	Organization of American States
PCR	Polymeraze Chain Reaction
RADA	Rural Agricultural Development Authority
UK	United Kingdom
WIBDECO	Windward Islands Banana Development Company

SECTION 1

- **Introduction**
- **Opening Session - Summary**
- **Workshop Goals and Objectives**
- **Discussions and Evaluation of Workshop**

INTRODUCTION

The Caribbean Black Sigatoka Management Workshop was held in Kingston Jamaica at the Hilton Kingston Hotel from October 2 to 5, 2001. The opening session was under the Chairmanship of Mr. Aaron Parke, Permanent Secretary, Ministry of Agriculture in Jamaica. Plenary sessions were held at the workshop location while practical sessions were organized at various appropriate locations including St. Mary Banana Estates and the Banana Industry Research Department Laboratory.

The Honourable Roger Clarke, Minister of Agriculture of Jamaica delivered the Keynote Address. Dr. Arlington Chesney, Director of the Caribbean Regional Centre, IICA Representative in Trinidad & Tobago and Acting Representative for Jamaica delivered the opening remarks. Mr. Sebastian Coppieters conveyed greetings on behalf of the Banana Export Company/European Union Support Programme (BECO EUBSP), and Mr. Byron Noble gave the Vote of Thanks on behalf of the Workshop organizers.

The four day event was attended by thirty-two participants and included representatives from fifteen (15) countries, namely Antigua and Barbuda, Barbados, Dominica, Grenada, Haiti, Jamaica, Suriname, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, The Bahamas and Trinidad and Tobago. Participating institutions included IICA, Jamaica Producers Group, Banana Export Company and the Windward Islands Banana Development Company (WIBDECO).

OPENING SESSION SUMMARY

Welcome and Introductions

Mr. Aaron Parke Permanent Secretary, Ministry of Agriculture

The Chairman, Mr. Parke welcomed the participants and gave an overview of black Sigatoka. He went on to congratulate IICA and the Banana Export Company for organizing the Workshop.

Opening Remarks

Dr. Arlington D. Chesney

**Director, Caribbean Regional Centre, IICA, Representative in Trinidad and Tobago and
IICA Representative a. i. in Jamaica**

The IICA representative conveyed greetings on behalf of IICA and noted the collaborative effort of the participating institutions viz. IICA, Jamaica Banana Export Company and the Governments of the Caribbean.

He remarked on recent events in the United States that pointed to an increased need to address issues of food security. He also observed that the liberalization of the single market in Europe has highlighted the importance of pest and disease control in safeguarding export markets. In this regard he pointed out several of the emerging concerns in agriculture associated with the application of chemicals e.g. residues in export products and worker protection.

Dr Chesney noted that the Workshop satisfied three goals:

- Partnership, which prevents conflict, avoid duplication and ensures efficient use of resources
- Emerging issues in Agricultural Health and Food Safety whereby efforts are directed at targeting and creating awareness of eminent problems in agricultural health and food safety instead of responding to emergencies only
- Train the trainer; the multiplier effect

Dr. Chesney informed that black Sigatoka is present in the Dominican Republic, Jamaica, Cuba and Haiti in the Caribbean region and in Florida, Brazil, Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Venezuela of the countries surrounding the Caribbean Sea. He noted that the disease is also present in West Africa and warned that the chances of entry into the non-affected countries of the Caribbean was very real, both by wind and especially with the help of man as a result of modern transportation, and because of the close proximity of the islands.

Dr. Chesney committed IICA to providing technical assistance in national capacity building. He acknowledged the need to modernize the agriculture sector and recognized the assistance of other support agencies such as the European Union who are working with regional governments and private sector organisations towards this end. He noted that the workshop was timely and wished for a successful outcome.

Greetings
Sebastien Coppieters
Technical Assistant
Banana Export Company/ European Union
Support Programme (BECO EUBSP)

Mr. Coppieters illustrated the impact of the European Union Banana Support Programme for Sigatoka Control in Jamaica. He provided a brief historic overview of the origins of the disease in Jamaica and the many challenges that have mitigated against good disease management and increased production in that country.

He commended the technicians working in Black Sigatoka management for their excellent work in establishing a structured programme for managing the disease in Jamaica and for the successes that have been achieved over the last five years. He noted successful features of the national programme such as; an aggressive spraying regime, research and education, the sensitisation of extension officers and farmers to the need of having an integrated approach to Sigatoka control. He expressed the view that the major problem affecting the level of Sigatoka control on most Jamaican small banana farms has to do with cash flow and resource management and he urged that absolute priority be maintained on the continued sensitisation of farmers within the agenda of the EU Banana Support Programme.

Mr. Coppieters expressed pleasure at collaboration with IICA and the anticipation of other joint initiatives on bananas.

Keynote Address
Hon Roger Clarke
Minister on Agriculture, Jamaica

The Minister of Agriculture welcomed those present and outlined the role of bananas and plantains in the economy of Jamaica and other countries in the region. He indicated that bananas was considered as an important crop both in terms of export earnings and domestic consumption hence black Sigatoka disease, which affects these crops, is a cause for concern.

Mr. Clarke paid tribute to Researchers at the Banana Export Company for their relentless efforts in the fight against the disease. He was pleased that they were willing to share their experiences with other CARICOM Partners.

He congratulated IICA and the European Union Project for collaborating in enabling the discussion on Black Sigatoka from which control strategies can be developed.

He stressed the significance of pest and disease management strategies and the many

challenges faced in that regard especially the need to be cognizant of residues and worker protection in the application of pesticides.

Mr. Clarke noted the specific aim of the Workshop to enhance skills in disease control. He thought that the Workshop was timely given the status of the disease in the Caribbean region and wished participants success in imparting the knowledge gained to colleagues in their respective countries.

He expressed pleasure in sharing the Jamaican research and management experience with CARICOM partners and reiterated that the challenges were not for Jamaica's consideration alone, or for the Windward Islands, but that the disease constituted a hurdle that the entire CARICOM Community should confront together.

He encouraged a spirit of collaboration among the participants and the broadening of cooperation, friendship, understanding and enterprise for the enhancement of the agriculture sector and for ensuring regional food security. In this context he expressed the need to publicly recognize the efforts of IICA in promoting the development of Regional Agriculture.

Vote Of Thanks

Mr. Bryon Noble

Agricultural trade Specialist, IICA

Mr. Noble expressed his gratitude to the persons at the head table for taking time off to address the participants. He thanked the many persons who assisted in the planning of the workshop and expressed the hope that it would be rewarding to all the participants.

DISCUSSIONS AND EVALUATION OF WORKSHOP

Overview

During the review session of the Workshop, participants were asked to give their impressions of the activities that had been undertaken and the quality of the technical presentations. All participants indicated that the Workshop was useful and was above their initial expectations. They lauded the efforts of the presenters both in terms of the content of the information and the teaching materials distributed. Most participants felt that they were equipped to train colleagues on their return.

Closing Remarks

Mr. Everton Ambrose, IICA gave the closing remarks. He noted that the workshop had resulted in four productive days and he expressed pleasure about the interactive manner in which the sessions had been conducted. He thanked Dr. Janet Conie and her team for a well-organized, efficiently implemented Workshop and for their willingness to share their experience so openly.

Mr. Ambrose outlined the expected objectives of the Workshop viz:

- To develop a model National Programme for black Sigatoka Control;
- To discuss black Sigatoka disease management strategy for various production regimes;
- To train trainers in the diagnosis and control of black Sigatoka disease;
- To develop strategy for preventing or retarding the entry of black Sigatoka

He was confident that these objectives had been met.

Mr. Ambrose urged the participants to take advantage of the training that they had received through this Workshop, to undertake the challenge to help delay or prevent the spread of black Sigatoka disease in the Caribbean and the entry into their respective countries.

SECTION 11

- **Technical Presentations and Practical Sessions**
- **Appendices**

Overview of Black Sigatoka Disease in Jamaica Caribbean

Janet Conie

Introduction

The production of bananas for carbohydrate dietary source, exportation and wage-provision has been of major significance to the Caribbean and specifically Jamaica since the 1950s. Currently, it is surpassed only by sugar cane in exports and the number of citizens employed by any agricultural industry in most countries. The exception to this is the Windward Islands, where banana production is the primary industry and employ up to 60% of the population. The yearlong production generates cash flow and employs approximately 20,000 employees directly, mainly located in the rural areas.

In recent years, there has been a consistent decline in export acreage and volumes, as a result of climatic and international market forces. Export banana in Jamaica had achieved its highest annual production of 105,000 export tonnes in the 1970s. In 1996, 87,000 tonnes was exported and 80,000 tonnes was consumed locally, all from 5,000 hectares. Total export for the year 2000 was 42,000 tonnes (Table 1). However, there has been an increasingly vibrant domestic market estimated conservatively at 92,000 tonnes in the year 2000 (The Stone Team, 2000). Ironically however, dedicated domestic banana acreages have been abandoned virtually, since the complete establishment of black Sigatoka in all areas of Jamaica over the last 5 years.

Table 1. Export Production of Jamaican Bananas.

Year	Export Tonnes
1990	62,660
1991	75,290
1992	76,723
1993	76,777
1994	78,577
1995	85,223
1996	87,433
1997	79,109
1998	61,938
1999	52,209
2000	42,000

The total of 132,000 tonnes that was produced in Jamaica during the year 2000 was cultivated on the 3000 hectares registered for export production. Productivity for 1996 was estimated at 33.6 tonnes per hectare, compared to 44 in 2000. The relative increase in productivity by 10.6 tonnes per hectare per year was achieved as a result of the implementation of very successful black Sigatoka disease management programmes, with financial assistance from the European Union. The programme started prior to the first diagnosis of the disease in northeastern Jamaica in August 1995. However after the outbreak, appropriate strategies for containment and management (which were pre-planned) were put into action. The programmes took into consideration the following constraints that were peculiar to a developing island nation: medium to low levels of technology, crop nutrition and educational background on many small farms; uneven topography (cultivations on hillsides and deep closed valleys); non-contiguous banana acreages and the proliferation of abandoned cultivations.

Banana Production and Areas Utilised

In Jamaica, the hilly regions of the east receive over 1500 mm of annual rainfall rising to 5000 mm in some areas. However, irrigation is necessary on the coastal plains, as well as the western and central hilly interiors. Irrigation is particularly needed in the two dry periods, March to April and July to September. The temperature averages 27C on the coast and falls with increasing altitude.

Approximately 80% of the Jamaican banana export acreage is managed in monoculture by three estates on flat lands on coastal plains or inland valley floors, using medium to high technology methods. The remaining 20%, is located on hilly terrain sloping greater than 20 degrees with low technology systems, consisting of non-contiguous acreages; occasionally inter-cropped with coconut, cocoa and coffee, and owned by over 270 registered farmers.

Many of the small farmers have no more than primary level education. In the last six months (November 2000 to April 2001), the number of actively exporting farmers on a weekly basis had declined from 272 to less than 100, as farmers alternate sales with the local market. This lack of dedication to export was caused by the high cost of production (inputs and labour), uncertainty of their ability to comply with world trade standards; the influence droughts and flooding; and increase in the domestic trade. From total production the estates, were able to export an average of 38 tonnes per hectare, while small-scale farmers export 20 tonnes per hectare.

Black Sigatoka Disease and Its Distribution

Yellow Sigatoka was detected in Trinidad in 1937 and discovered in the other Caribbean territories one year later (Stover 1962). The more virulent black

Sigatoka was first discovered in Cuba in 1992 (FAO 1993), Jamaica in 1995 and the Dominican Republic in 1997 (INIBAP 1997). The Antilles is currently free from black Sigatoka disease.

When black Sigatoka was discovered in Jamaica, an immediate undocumented survey of the island revealed that the disease was present in the eastern and western ends of the island only. It was evident that the outbreak first occurred in the east and had unknowingly spread to the west by way of infected sword suckers of plantains that were used for planting material. By the end of 1997 the disease had spread to all regions of the island and replaced yellow Sigatoka (except at high elevations where the diseases coexist on banana and plantain plants). This rate of spread was similar to that in other areas of the world, with the exception of Australia (Gowen 1995). This occurred because eradication programmes similar to that in Australia (Jones 1990) were not carried out and resources were not available to enforce recommendations to curtail the movement of banana trash packaging and planting materials from infected areas.

Management of Black Sigatoka in Jamaica

1. Diagnosis of black Sigatoka

Diagnosis of the first black Sigatoka outbreak was carried out by the identification of conidial scars and simple conidiophores with microscopy. Confirmation was made with the use PCR at the Natural Resource Institute UK. After confirmation in 1995, it became extremely important for field officers to be capable of diagnosing black Sigatoka, distinctly from yellow Sigatoka, for the purposes of a national survey that was carried out. The survey determined the spread of the disease across the island. Distinction between the two diseases in the field was fairly simple when the main guidelines were followed. Symptomatic lesions of the last streak stage (stage 3 of the Brun 1963 classification) of yellow Sigatoka is lighter in colour (light brown) compared to the dark brown to black shade of final streak stage of black Sigatoka. The field identification technique was imparted by Frans Wielemaker from Honduras in a weeklong training session. (Laboratory confirmation by way of conidial structures was used in cases where field diagnosis proved difficult).

2. Preparedness for Black Sigatoka disease outbreak in Jamaica

From 1989 to 1992, Jamaica embarked upon a programme preparedness for the inevitable outbreak of black Sigatoka. Researchers participated in extensive workshops and study tours with CORBANA in Costa Rica. All aspects of the management of black Sigatoka were studied in detail. Skills

and technologies were adapted to the Jamaican conditions in the following manner.

- i)** A multi-site, on-farm project to adapt the biological and climatic forecasting methods for the prediction disease outbreaks and to progressively measure disease intensity, was initiated (Dixon and Conie 1992). The methods were applicable to yellow and black Sigatoka, and instrumental in the detection and management of the first outbreak in 1995.
- ii)** In 1992 to 1993, an island-wide series of seminars and workshops was carried out. Relevant technical personnel were targeted from various divisions: - quarantine services; banana, coffee, coconut and cocoa industries, as well as Ministry of Agriculture extension workers; port workers; national information service personnel and policy-makers. The objectives of the training were to make the participants aware of the following aspects:
 - a) The effects of black Sigatoka;
 - b) The means of entry into the island and mechanisms of spread;
 - c) Methods of disease containment and quarantine;
 - d) Diagnosis of black Sigatoka in the field and the differentiation; Between black and yellow Sigatoka disease symptoms;
 - e) Management strategies for black Sigatoka on export and non-export farms; and
 - f) Use of resistant varieties.

The programmes were broadcast nationally by way of print, radio and television media. A similar awareness programme sponsored by IICA is currently underway in the Antilles, in preparation for the advent of black Sigatoka.

- iii)** A manual on "Sigatoka Disease Control" was prepared and circulated to all extension officers in (Dixon and Conie 1992). The manual was updated in 2000 (Eds, Conie, Elvey and Coppieters (2000)).
- iv)** A national policy decision was made that all new national banana production expansion or development programmes (for small farmers) were mandated to have a centrally managed Sigatoka disease management unit (DMU). The DMU has been a very successful component of a development programme in western Jamaica WESTBAN (1994 1999) and the current European Union Banana Support Programme (EUBSP) since 1996. In addition to technical advisories and farmer training for cultural and chemical Sigatoka disease control, the DMU must have certified ground spray teams and a guaranteed supply of

chemical inputs.

- v) A continuous supply of leaf spot control chemicals and all other inputs, which are necessary for optimum crop nutrition and cultural practices that impact upon the intensity of the disease, were also acquired, guaranteed and made available to all export farmers. Currently, a credit scheme for inputs is operated by the Banana Trading Company (BTC), which is subsidiary of the Banana Export Company (BECO).

3. Disease Management Strategies Used in Jamaica

The rigid chemical management strategy used for the more virulent black Sigatoka requires more frequent application of fungicides than for yellow Sigatoka. An example of a current management strategy is given in Table 2, for areas in the high rainfall areas of northeastern Jamaica.

Chemical control is always augmented by particular essential cultural practices, which can never be over-emphasized. These include optimum crop nutrition; control of root and corm pests, plant population, weeds, drainage; and fungal inocula (removal of trash or infected leaves). To this end, the EUBSP has strengthened of extension service of the export banana industry and provided grants and revolving loans for farmers to carry out the necessary husbandry.

4. Climatic and Biological Disease Forecasting Strategies

The number and frequency of fungicide applications were reduced significantly in areas of lower rainfall and when climatic and biological disease forecasting strategies were utilised. The forecasting methods (Conie and Dixon, 1992) are based upon several parameters: evaporation measured by Piche evaporimeter (Ganry and Meyer, 1972) rainfall and temperature; subsequent disease development; (Cronshaw 1987) and age of youngest leaf infected (Stover 1972). These methods were modified for black Sigatoka in Jamaica and have been very successful. They are used currently by the DMU of the European Union Banana Support Programme for small farmers and on the large estates. The 29 applications outlined in Table 2 were decreased to 18 - 26 in various locations, according to rainfall and evaporation levels. Before 1995, the number of applications to control yellow Sigatoka ranged from 12 - 22.

Table 2. Black Sigatoka Spray Schedule for High Rainfall Areas in Jamaica

Time of year	Weather Conditions	Fungicide	Application Base
January	WET	Tilt	Oil
↓		Bankit	Emulsion
February	DRY	Benlate	Emulsion
↓		Calixin	Emulsion
↓		Manzate	Water
March		Bravo	Water
↓		Benlate	Emulsion
↓		Calixin	Emulsion
April		Benlate	Oil /Emulsion
↓	Rain expected	Calixin	Oil /Emulsion
May		Benlate	Oil
↓	WET	Calixin	Oil
↓		Benlate	Oil
June		Tilt	Oil
↓		Bankit	Emulsion
July		Calixin	Emulsion
↓	DRY	Benlate	Emulsion
↓		Manzate	Water
August		Bravo	Water
↓		Calixin	Emulsion
September	Rain expected	Tilt	Oil /Emulsion
↓		Benlate	Oil /Emulsion
October		Calixin	Oil /Emulsion
↓	WET	Benlate	Oil
↓		Calixin	Oil
November		Benlate	Oil
↓		Tilt	Oil
December	WET	Bankit	Emulsion
↓		Calixin	Oil

5. Current Research Efforts in Black Sigatoka Management

The Research Programme in Sigatoka disease management in Jamaica was strengthened in 1996 and is currently totally supported by the European Union. The monitoring of the national Sigatoka disease programme is one of the primary functions of the Research Department.

i) Fungicide Sensitivity Monitoring

Fungicide sensitivity monitoring of *Mycosphaerella fijiensis* is carried out for specific reference areas across the island. The

fungicides (propiconazole, benomyl, azoxystrobin and tridemorph) and are tested periodically. The pathogen has maintained commercially acceptable sensitivity levels to all fungicides, with the exception of propiconazole on one isolated farm in St. Catherine (Table 3). Reduced sensitivity was discovered in Bog Walk in January 1998, after which triazole was completely withdrawn from the programme, until July 2000 when increased sensitivity was observed. The Research Department formulates appropriate chemical strategies for all export farms and especially those with peculiar disease problems.

Table 3. Percentage Inhibition of Germ Tube Growth of Sigatoka Ascospores from Bog Walk (St. Catherine, Jamaica).

Date of Sampling	Percentage Inhibition at 1 pm propiconazole
January 1998	34.0
November 1998	44.0
July 2000	66.0

N.B. Loss of sensitivity to the fungicide in the field is 50 % inhibition.

ii) Evaluation for Efficacy and Suitability of New Fungicides for Incorporation into the Management Programme.

The Research Department has the responsibility to carry out replicated trials to test all new products or formulations for the Banana Industry. Each year, at least one Sigatoka fungicide trial has been carried out. Some of the chemicals that were tested proved to be incapable of maintaining commercially acceptable disease control. Products found suitable are incorporated into the management programme whenever they are made available to the local industry (Conie and Young (1999a and 199b), Conie and Magnus (1995) and Conie and Dixon (1993)).

iii) Training of Technology Transfer and DMU Officers.

Training of new extension officers and periodic re-training of DMU technicians, data collectors and farm supervisors, are also routinely carried out by the Research Department Pathology Unit.

iv) Advisory Farm Visits, Troubleshooting and Emergency Investigations.

The Pathology Unit also has the responsibility to investigate peculiar disease-related problems on commercial farms and provide solutions or proposals for further research that may be necessary.

6. Host Plant Resistance

Among the disease management technologies, improved cultivars with high levels of resistance or tolerance to Sigatoka disease offer solutions for the guarantee of a domestic market supply. Cuba is reported to have embarked on a successful programme in this regard (anonymous). Resistant varieties will become more necessary for local consumption and the by-products trade in Jamaica when there is no support from export production. The creation of value-added goods from traditional export commodities is being promoted and is increasing in Jamaica.

Preliminary evaluations of cultivars from Jamaica, FHIA and IITA programme were started in Jamaica in 1996. However, the major programme was deferred due to lack of local acceptance of the varieties; unsuitability for export; scarce resources and political will; and the discovery of somatic banana streak virus (BSV) in some of the TMPX plantain hybrids. Subsequently, another project was started. Cultivars developed in Jamaica (RG1) and by the Honduran Foundation for Agricultural Research (FHIA) (FHIA 1, 3 and 21) were multiplied for evaluation and distribution. However, this Ministry of Agriculture programme was severely curtailed as a result of the negative influence of micro-propagation on the development of BSV in FHIA 21 (INIBAP 1997), and outbreaks of black Sigatoka on RG1 and yellow Sigatoka on FHIA 1 banana cultivars. The Ministry of Agriculture project is on going but FHIA 21 cultivars are being multiplied by conventional *in vivo* methods.

A new programme, which will be supported by the EU to supply plantains mainly for the export and chips trades, is yet to be initiated. The project will be complimented by a regional research project, which will be funded by and the OAS in collaboration with CABI, and has been recently been approved. The aim of the latter is to evaluate non-resistant and resistant plantain varieties in an integrated pest management programme.

Socio-economic Aspects of Sigatoka Disease

A socio-economic survey was carried out in Jamaica by the Stone Team in the year 2000. The aims of the survey were to determine the farmers impressions of the Banana Industry export market; reasons for the farmers moving away from the export market and the impact of local consumption on the export market. It was ascertained from the survey that the control of black Sigatoka over the last five years was not one of the reasons given for the decline in export industry. Of the 80 farmers interviewed, 77% believed that the leaf spot control was more effective in 2000 than five years earlier (Table 4). However, a similar percentage of farmers said the cost of control was expensive. The current cost of Sigatoka control on small farms is 8 - 18% of the cost of production (Table 5). The lower cost of control was incurred by dedicated exporters who benefit fully from DMU services.

Farmers who consistently supply the Banana Export Company are provided with loans, chemicals on credit or crop lien basis, as well as regular technical advice. In spite of this, the Stone survey revealed that 25% of farmers believed that the returns from the export trade were too low and 35% say that the cost of production is too high (Table 6). However, 85% of farmers recognized that the local trade is unable to absorb the total banana production (Table 7). Therefore, farmers chose not to abandon the export trade completely. They will however, export infrequently and dispose of portions of the weekly production on the local market. It is believed that farmers, who currently export, remain loyal to that trade for the benefits and the security, but they do at times, dispose of an overall average of 75% of the production on the local market. Hence, the support services are significant in ensuring good quality banana for both the export and domestic banana supplies.

With exception of the distribution of planting material, there has been virtually no effective developmental support for local banana and plantain production. As a result plantain production has seen a significant decline.

Table 4. Comparing leaf spot control with five years ago.

Effectiveness	Much better today	77
	More difficult to deal with	11
	More or less the same.	12
Cost	Much more expensive now	77
	More affordable now	8
	More or less the same.	15

Adapted from the Stone Team Survey 2000.

Table 5. Annual Cost to the Farmer of Chemical Control for black Sigatoka in Jamaica (for 22 applications).

	Small Farms		Estates
	Totally Centrally Managed (US\$/hectare/year)	Others (US\$/hectare/year)	US\$/ hectare/ year
Total cost of chemical control	1,076.48	1,555.83	1,442.70
% Of total production cost	8.4	18.0	17.0

- N.B. 1) Small farms are of size 0.5 to 40 hectares and are ground sprayed. Estates (40 - 800 Hectares) are sprayed by aircraft.
 2) Small farmers that are categorized as "others", benefit only in the way of advisories and training from the Disease Management Unit; are not sprayed directly by Disease Management Teams; and incur greater labour costs.

Table 6. Reasons for Decline in Jamaican Export Banana Trade over the Period 1997 - 2000.

Why Farmers Stopped Exporting	Percentage (%)
Grading too stringent / too much rejection	30
High input / production costs	35
BECO has no time for small farmers	30
Export price too low	25
Bad management by banana officials	16

Adopted from the Stone Team Survey 2000.

Table 7. Stone Survey 2000 on the Possibility of Local Market Absorbing total Banana Production at Profitable Price to

Answer to Question: Can local market absorb total production?	Percentage (%)
Yes	9
No	85
Don't know	6
Total	100

Adopted from the Stone Team Survey 2000.

The Future of Bananas and Sigatoka Management

The local and export banana markets for Jamaican bananas continue to express a definite preference for Cavendish cultivars. As long as these susceptible varieties are produced, a costly but effective Sigatoka disease control programme will remain critical to the supply of this traditional carbohydrate food source. However, resistant varieties will become necessary if or when resources are no longer available to control the disease economically. Many believe this scenario is imminent for Caribbean territories and other ACP nations, as a result of globalisation. Therefore, it is necessary to embark upon or continue programmes to breed, evaluate, multiply and distribute resistant or more tolerant cultivars. Some varieties are currently available as a result of international research programmes utilising biotechnology of both conventional breeding and genetic engineering methods. However, standards of acceptability of the local and overseas markets and consumers will have to be modified in order to accommodate the peculiarities of genetic origin and composition or postharvest fruit quality of the new varieties.

References

- Conie, J. and Dixon, J. (1992) Improved Sigatoka Management: One Factor to Increase Productivity for Banana Farmers in Jamaica. *Research Department Reports (1987-1994)* 11-30.
- Conie, J.E. and Dixon, J.A. (1993) The Efficacy of Topsin OD vs. Benlate OD in the Control of Yellow Sigatoka Disease. *Report of the Research Department, Banana Board (1987-1994)*. 31-35.
- Conie, J, Elvey, D and Coppieters, S. (Editors) (2001) *Managing Black Sigatoka Disease in Banana*. A Clifton Wilson compiled *Training Manual for Spray Technicians*. EU Banana Support Programme / Banana Export Company Jamaica. 1 pp 27.
- Conie, J. and Magnus, A. (1995). The Efficacy of Bravo 720 vs. Benlate OD in the control of Yellow Sigatoka Disease of Banana. *Report of the Research Department of the Banana Board (1995-1999)* p. 71-76.
- Conie, J. and Young, M. (1999) Banana Board Research / BASF / EU Fungicide Efficacy Trial. *Report of the Research Department Banana Board Jamaica (1995 - 1999)* 26-38.
- Conie, J. and Young, M. (1999) Banole Banana Spray Oil Efficacy Trial. *Report of the Research Department Banana Board (1995-1999)*. 47-54.

- Dixon, J. and Conie, J. (1992a) Forecasting for Improving Management of Sigatoka Disease in banana in Jamaica. *JARP Annual Report and Research Highlights*. 37-40.
- Dixon, J. and Conie, J. (1992). *Sigatoka Disease Management Manual*. Banana Board. Jamaica
- Cronshaw, D. K. (1982) Management of Banana Leaf Spot (Sigatoka) Disease in the Windward Islands. *Tropical Pest Management*. **28** (2), 136-146.
- FAO (1993) *FAO 1992 Yearbook (Volume 46)*. Food and Agriculture Organisation. Rome.
- Ganry, J and Meyer, J.P. (1972) La lutte controlee le *Cercospora* aux Antilles. *Fruits*, **27**, 665-676.
- Gowen, S. (1995) *Bananas and Plantain*. Natural Resource Institute and Department of Agriculture UK 343-356
- INIBAP (1997) Sigatoka Leaf Spot Diseases. *Musa Disease Fact Sheet No. 8* INIBAP Montpellier France.
- Jones (1990) Black Sigatoka A Threat to Australia. In Fullerton R. A. and Stover R.H. eds. *Sigatoka Leaf Spot Disease of Bananas*. INIBAP Montpellier France. 38-46.
- Stover 1962 Intercontinental Spread of Banana Leaf Spot (*Mycosphaerella musicola* Leach). *Tropical Agriculture* Trinidad. **39**, 327-338.
- Stover, R.M. and Dickson, J.D. (1970) Leaf Spot of Bananas caused by *Mycosphaerella musicola*. Methods of Measuring Spotting Prevalence and Severity. *Tropical Agriculture*, Trinidad, **47**, 289-302.
- The Stone Team (2000). *Banana Industry Survey*. Banana Export Company. Jamaica. pp.20.

Life cycle of (*Mycosphaerella fijiensis*) And epidemiology of black & yellow Sigatoka Diseases

Marina Young & Janet Conie

Influence Of Various Parameters On The Development Of Black Sigatoka

Black Sigatoka is well suited for environmental conditions prevailing in the coastal tropics and has virtually replaced Yellow Sigatoka as the dominant leaf spot disease in these areas.

ALTITUDE & TEMPERATURE

Temperature affects:

- PLANT GROWTH
- DEVELOPMENT
- METABOLISM
- PRODUCTION

Plant	M. Fijiensis
Range 14C - 38 C Optimum 22C - 28C < 16C LEAF FORMATION & PLANT GROWTH SLOWED; < 12C COAGULATION OF LATEX, FAST RIPENING OF FRUITS	Conditions that favours plant growth also favour disease development

- x any altitude is suitable for banana cultivation.
- x Yellow Sigatoka develops faster than black Sigatoka at the higher altitudes (effect of temperature);
- x *M. fijiensis* is more susceptible to low temperatures than *M. musicola*

Yellow Sigatoka seems more adapted to cooler environments than black Sigatoka. But Black Sigatoka is gradually adapting to the cooler environments (example: In Costa Rica in 1985, both yellow & black Sigatoka disease were identified on the

same banana leaf at 900 m, but only yellow Sigatoka was found at 1200 m (Romero & Gauhl, 1988) In 1990, in the same area of Costa Rica as was surveyed in 1985, black Sigatoka was found at altitudes up to 1500 m (F. Gauhl & C. Pasberg-Gauhl, 1999) In 1988, 7 years after its introduction to Colombia, black Sigatoka was found for the first time in the plantain producing areas in the Gauca valley at 1500m (Merchant, 1990). In 1991, it had reached 1600m (Belalcazar, 1991).

IMPORTANT CONCLUSION:

AT FIRST, YELLOW SIGATOKA WAS PRESENT ONLY AT LOW ELEVATIONS, BUT DUE TO PRESENCE OF MORE VIRULENT BLACK SIGATOKA, IT MOVED TO THE HIGHER ELEVATIONS.

THEREFORE, IT IS QUITE POSSIBLE, THAT BLACK SIGATOKA CAN BE ADAPTED TO HIGH ELEVATIONS



BE VERY CAREFUL IN MOVEMENT OF PLANT MATERIAL FROM LOW TO HIGH ELEVATIONS!!!

SOME OF ASCOSPORES WILL BE ABLE TO GERMINATE AT LOW TEMPERATURES, AND THEY WILL FORM THE CURVE:

LIGHT INTENSITY

- SHADING CAN PREVENT SYMPTOMS EXPRESSION (Meredith, 1970)
- SHADE DECREASED THE LEAF AREA AFFECTED BY SIGATOKA BY UP TO 50% (F.Gauhl & C. Pasberg-Gauhl, Costa Rica, 1999).

Differentiation of Sigatoka pathogens

- Both pathogens can be distinguished by the imperfect stage of *Cercospora*
- There are no distinguishing differences among the perithecia or *Mycosphaerella* stages.
- Visual symptoms in the field may suggest differences but are not sufficiently distinctive to separate yellow from black Sigatoka

- Both can be differentiated microscopically by the CHARACTERISTICS OF THEIR CONIDIA AND CONIDIAPHORES (Meredith & Lawrence, 1969, 1970); Mulder & Stover, 1976)

Two major morphological differences between Yellow and Black Sigatoka pathogens

Description	<i>M. musicola</i>	<i>M. fijiensis</i>
Production of conidia	The <i>Cercospora</i> stage of <i>M. musicola</i> is always produced on <u>sporodochia</u> *	The <i>Cercospora</i> stage of <i>M. fijiensis</i> is produced on simple conidiophores (or less frequently on small sporodochia)
Presence of scar (=thick helium)	The conidia do not have a scar at the end attached to the sporodochium	A scar is formed on the conidium and the conidiophore where the conidium was attached

*Sporodochia is the mass of tightly aligned conidiophores on a dark stroma.

Characteristics of the sexual stages of *M. fijiensis* & *M. musicola*

(Meredith & Lawrence, 1969, 1970; Mulder & Stover, 1976)

- SPERMOGONIA DEVELOP AT THE STAGE WHEN STREAK TURN INTO SPOT
- SPERMOGONIA ARE MORE ABUNDANT ON THE LOWER SURFACE OF THE LEAF.
- PERITHECIA ARE IMMERSED IN THE LEAF. THEY VARY IN CHARACTERISTICS, BUT ALMOST GLOBOSE WITH A DIAMETER OF 47-85 UM.
- ASCOSPORES HAVE DIMENSIONS OF 12.5 16.6 u x 2.5 3.8 u AND ARE TWO-CELLED, WITH THE LARGER CELL UPPERMOST IN THE ASCUS
- THE ASCOSPORE IS SLIGHTLY CONSTRICTED AT THE SEPTUM (Mulder & Holliday, 1974)

INFECTION

[T°, HR & Influence of micro flora]

- SPORE USUALLY GERMINATE WITHIN 2-3 HOURS OF DESPOSITION ON MOIST LEAF SURFACE

Temperatures for the development of ascospore germ tubes		
Minimum	Optimum	Maximum
12°C	27°C	36°C

-No development-taking place at 11°C and 38°C.

-At 20°C ascospore germ-tube growth is half the rate it is at 27°C.

OPTIMUM TEMPERATURE FOR CONIDIOSPORE GERMINATION & GROWTH IS 22-24°C.

- GERM TUBES FROM BOTH CONIDIA & ASCOSPORES PENETRATE THROUGH STOMATA AFTER 48-72h ABOVE 20°C (Stover, 1980; Foure & Moreau, 1992)
- ALL LEAVES ARE EQUALLY SUSCEPTIBLE TO *M. fijiensis*, HOWEVER, MOST INFECTIONS OCCUR ON NEW LEAVES BETWEEN EMERGENCE AND UNFURLING (Stover & Simmonds, 1987; Gauhl, 1994).

Effect of temperature on the germination of conidias (Turrialba, Costa Rica. 1991)

Temperature °C	Percentage of germination	
	<i>M. musicola</i> (at 1350 m)	<i>M. fijiensis</i> (at 600 m)
15	56.7	8.0
20	99.0	74.4
25	99.0	98.0
30	99.0	99.0

INCUBATION PERIOD

(Time between infection and appearance of the first speck symptoms on the leaf)

HUMIDITY
TEMPERATURE
INTENSITY OF INFECTION
PLANT VIGOR

Duration of incubation period:

11-105 days

UNDER IDEAL CONDITIONS: 10-14 DAYS

12-21 DAYS (Costa Rica.)

INCUBATION PERIOD CONSISTS OF:
(SIMILAR FOR BOTH YELLOW & BLACK SIGATOKA)

◆ GERMINATION

◆ PENETRATION (intercellular penetration)

◆ INFECTION (CELL PENETRATION)

(48-72-96 h) depends on RH & T°

- LENGTH OF INCUBATION PERIOD DOES NOT SEEM TO CORRELATE WITH OVERALL RESISTANCE (Foure, 1985);
- OTHER WORKS FOUND NO SIGNIFICANT DIFFERENCES BETWEEN INCUBATION TIMES IN DIFFERENT CULTIVARS (Gauhl, 1994; Mobambo *et al.*, 1996, 1997);
- INCUBATION PERIOD IS FASTER ON 3-5-MONTH-OLD PLANTS DERIVED FROM TISSUE CULTURE THAN FIELD-ESTABLISHED PLANTS (Foure & Mouliom-Pefoura, 1988; Pasberg-Gauhl, 1993; Mobambo *et al.*, 1997);

ARTIFICIALLY INNOCULATED FHIA -01® YOUNG PLANTS DERIVED FROM TISSUE CULTURE HAD INCUBATION PERIOD 4 DAYS LONGER THAN IN SUSCEPTIBLE 'GRANDE NAINÉ' YOUNG PLANTS (Romero & Sutton, 1997).

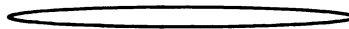
- Incubation period varied according to the isolate of *M. fijiensis* used in inoculations.
(isolates from Cameroon were more aggressive than those from Central America and South Pacific (Romero & Sutton, 1997).

INCUBATION PERIOD IS INFLUENCED BY THE SEASON:

In dry season there is delay in infection because of unfavourable conditions for ascospore discharge and germination, as well as temperature differences (affects mycelial growth in leaf tissues).

PATHOGENESIS

1st – SPORE LANDS ON THE LEAF



- SPORE IDENTIFYS IF HOST IS SUSCEPTIBLE OR RESISTANT;

- SPORE HAS NUTRIENTS FOR FEEDING DURING LANDING AND BEFORE CELL PENETRATION

2nd - GERMINATION OF THE GERM TUBE & FORMATION OF EPIHILLIC MYCELIUM



FORMATION OF APRESSORIA ABOVE THE STOMA & FORMATION OF FINE MYCELIUM FOR PENETRATION



DIRECT PENETRATION THROUGH THE STOMATA & FORMATION OF VESICLES



VESICLES ARE FORMING FINE MYCELIUM



PENETRATION OF MYCELIUM THROUGH INTERCELLULAR SPACES BETWEEN THE LEAF PARENCHYMA CELLS



3rd -DIRECT PENETRATION THROUGH THE CELL WALL

(from this moment pathogen become an obligate parasite)



CELL PENTRATION RESULT IN NECROSIS OF STOMATAL CELLS
(Possibility that pathogen uses special ferments for dissolving of the cell wall (??))

**4th - APPEARANCE & DEVELOPMENT OF SYMPTOMS
(DEPENDS ON HOST SUSCEPTIBILITY)**



ACCELERATION OF COLONIZATION RATE



APPEARANCE OF SPOTS DEPENDS
ON THE CLIMATIC CONDITIONS &
HOST GENOTYPE

AFTER INITIAL INFECTION IS ESTABLISHED, ONE OR MORE
VEGETATIVE HYPHAE OF *M.fijiensis* EMERGE FROM STOMATA
ON THE LOWER LEAF SURFACE



DEVELOPS INTO CONIDIOPHORES OR GROW
ACROSS THE LEAF SURFACE PARALLEL TO
THE VEINS FOR DISTANCE UP TO 3 mm TO
INFECT ADJACENT STOMATA



AT VARIOUS INTERVALS ALONG THE
HYPHAE, SHORT SIDE-BRANCHES DEVELOP,
WHICH TERMINATE AS APPRESSORIA OVER
STOMATA.

MOVEMENT FROM ONE STOMATA TO
ANOTHER IS MUCH MORE COMMON WITH
M.fijiensis THAN *M.musicola*



**THIS PROCESS RESULTS IN THE DEVELOPMENT OF BLACK LEAF
STREAK LESIONS OVER ENTIRE LEAF**

DISEASE SEVERITY INCREASES THE LONGER THE PERIOD OF
LEAF WETNESS

INFECTION PERIOD RESULTS IN:

- MASS PRODUCTION & RELEASE OF ASCOSPORES ON THE TREE
(infected leaf can release and produce ascospores for 18-20 days)
- MASS PRODUCTION & RELEASE OF ASCOSPORES IN THE LEAF ON
THE GROUND (UP TO 5-8 WEEKS!!!)



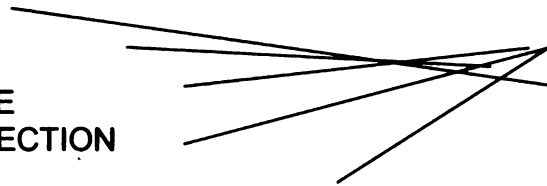
Sanitation is important in reducing of level of ascospore inoculum!!!

WHEN POTENTIAL INFECTION IS ESTIMATED, INFECTED LEAVES ON THE GROUND MUST BE CONSIDERED.

5th - SYMPTOM EVOLUTION TIME

(The number of days between the appearance of first symptoms and the appearance of mature spots with dry centres)

HUMIDITY
TEMPERATURE
LIGHT INTENSITY
HOST RESISTANCE
INTENSITY OF INFECTION



- THE SUSCEPTIBILITY OF THE CULTIVAR (example of symptom development on 'Valery' vs. 'Currare' – plantain subgroup) AND
- ENVIRONMENTAL CONDITIONS
(SYMPTOM EVOLUTION TIME RANGING FROM 11 TO 139 DAYS)
- LIGHT INTENSITY (SHADING)

SHADING CAN PREVENT SYMPTOM EXPRESSION
(Meredith, 1970)

SHADE DECREASED THE LEAF AREA AFFECTED BY SIGATOKA BY UP TO 50% (F.Gauhl & C. Pasberg-Gauhl, Costa Rica, 1999).

RATE OF ONSET OF MATURE SPOTS IS MUCH FASTER WITH BLACK SIGATOKA THAN WITH YELLOW SIGATOKA (8-10 DAYS EARLIER)

AS A CONSEQUENCE, SPOTS APPEARED ON LEAVES 3-4 AND SOMETIMES LEAVES 2-4 COMPARED WITH LEAVES 4-5 WITH YELLOW SIGATOKA (Stover, 1980)

This increased speed of development, coupled with higher infection densities due to earlier and more abundant formation of ascospores, makes black Sigatoka so much more difficult to control than yellow Sigatoka

6th - SEXUAL REPRODUCTION

(Period from the formation of necrotic spot to appearance of mature spot with grey centre)

7th - ASCOSPORE LIBERATION

AFFECTED BY LEAF WETNESS OR DRYNESS

CONIDIOPHORES AND CONIDIA

- PRODUCTION OF CONIDIA & CONIDIOPHORES OF *M.fijiensis* IS SHORT DURATION.

Black Sigatoka – conidia produced at stage III (STREAK)
Yellow Sigatoka – conidia produced at stage IV (SPOT)
- CONIDIA BECOME DISLODGED BY WIND AND WATER (WATER-SPLASH).
BASED ON MORE RECENT RESEARCH FINDINGS WIND HAS BEEN IDENTIFIED AS THE MAIN AGENT THAT CARRIES CONIDIA TO NEARBY PLANTS (Rutter *et al.*, 1998)
- THE SCARS ON THE CONIDIA & CONIDIOPHORES AT THE POINT OF ATTACHMENT ARE BELIEVED TO FACILITATE THE WIND REMOVAL OF CONIDIOPHORES
- CONIDIA ARE NOT USUALLY FOUND IN THE AIR ABOVE CANOPY OF PLANTATIONS
- NO DISTINCT CONIDIAL INFECTION PATTERNS APPEAR ON LEAVES (for yellow Sigatoka spotting usually at the ‘tip’ or in line pattern)

CONIDIA DO NOT PLAY A MAJOR ROLE IN DISEASE SPREAD, BUT MORE ADAPTED FOR EXISTENCE IN THE ENVIRONMENT THAN ASCOSPORES

PERITHECIA & ASCOSPORES

- PERITHECIA ARE ABUNDANT IN MATURE LESIONS (STAGE 5 – Brun CLASSIFICATION; STAGES 5-6 –Foure CLASSIFICATION);
- ASCOSPORES ARE FORCIBLY EJECTED FROM THE PRITHECIA DURING PERIODS OF WET WEATHER (event of rain is important), OR IN THE ABSENCE OF RAIN (0.1 – 0.2 mm is enough to initiate release of ascospores), DURING THE DAY (max. release before dawn as dew settles);

PRESENCE OF WATER IS NECESSARY FOR THE DISCHARGE OF ASCOSPORES (SEASONAL PATTERN – high number in wet period & low number in dry period). For example the highest concentration of ascospores per one day was 6876/ m³ of air on 26.12.85 (Meredith *et al.*, 1973);

- Ascospores discharge occur within 1 hour or so after rain.
- Temperature affects ascospore production (daily average 20°C or below), and release (below 20°C, or above 33°C);
- ASCOSPORES CAN BE RELEASED FROM LESIONS UP TO 21 WEEKS AFTER THEIR FORMATION & PRODUCTION;
- PRODUCTION OF ASCOSPORES ARE GREATER ON THE UNDERSURFACE OF LEAF
- ASCOSPORES ARE THE MORE COMMON FORM OF INOCULUM (epidemiological studies in Costa Rica, Colombia & Nigeria)
- ASCOSPORES ARE COMMONLY FOUND IN THE AIR ABOVE CANOPY OF PLANTATIONS FOLLOWING RAINFALL (movement to other plants within plantation and to other plantation)

Ascospores are killed after 6 h exposure to the ultraviolet radiation ⇒ dissemination of ascospores determined not only by the speed of the wind, but also by cloud cover at the time of ascospores release)

How irrigation can influence on the release of ascospores?

Comparison of sexual cycles of yellow & black Sigatoka

M. musicola

M. fijiensis

Yellow Sigatoka produces lower number of ascospores in comparison with black Sigatoka	Black Sigatoka produces greater number of ascospores
Yellow Sigatoka has only few sexual cycles per year	Many sexual cycles per year (for better adaptation, since certain types of banana may be difficult to attack)

Sexual process cannot be reproduced under the laboratory condition, otherwise, it would be possible to identify genes for resistance.

Effect of Yellow Sigatoka pathogens on VEGETATIVE GROWTH of banana in the tropics

LEAF 2-5 ARE THE MOST EFFICIENT LEAVES FOR PHOTOSYNTHESIS



[IMPORTANT TO KEEP LEAVES FREE OF

- EXCESSIVE SHADE,
- SEVERE LEAF TEARING AND
- DISEASES]

LEAF EMISSION RATE OF CAVENDISH SUBGROUP (AAA) IS 7-8 DAYS
(UNDER OPTIMAL CONDITIONS)



THE MOST EFFICIENT AREA RENEWED MONTHLY

YELLOW SIGATOKA HAVE LITTLE EFFECT ON VEGETATIVE GROWTH AS MEASURED BY:

- THE RATE OF LEAF EMERGENCE
- RATE OF INCREASE IN PLANT HEIGHT
- HEIGHT OF THE PLANT AT THE TIME OF SHOOTING

Effects of disease are not significantly great on leaves 2 – 5.

Effect of yellow & black Sigatoka on fruit development

AFTER SHOOTING, LEAF PRODUCTION CEASES & PLANT IS UNABLE TO REPLACE LEAVES DAMAGED BY SIGATOKA.

- PLANT PRODUCES SMALLER BUNCH
- SIGATOKA ALSO DISTURBS THE PHYSIOLOGY OF FRUIT, RESULTING IN PREMATURE RIPENING (IN THE FIELD OR DURING THE TRANSIT).

Effect of black Sigatoka on the vegetative growth of banana

LEAF 2-5 ARE THE MOST EFFICIENT LEAVES FOR PHOTOSYNTHESIS

**When 30-40% of leaf surface is affected with black Sigatoka
= PHOTOSYNTHESIS IS ZERO!**

**ON A GROWING PLANT, STREAKS ARE USUALLY PRESENT ON LEAVES
NUMBER 3, 4 & 5**

BOTH STREAKS AND SPOTS ARE PRESENT ON LEAVE 5 AND OLDER

**IF THE PLANT IS STRESSED AND SLOW-GROWING, ADVANCED SYMPTOMS
MAY BE SEEN ON THE 2ND AND EVEN THE 1ST LEAF**

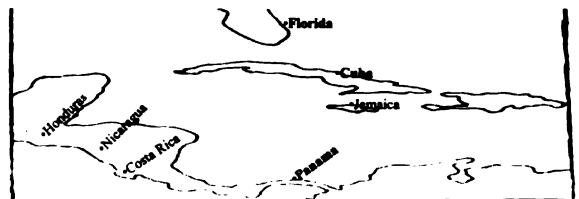
- **IT USUALLY TAKES 3-4 WEEKS AFTER SYMPTOMS FIRST APPEAR FOR A LEAF TO DIE (Stover, 1972; Gauhl, 1994)**
- **UNDER CONDITIONS WHEN STREAKS COALESCE, LARGE BROWN AREAS ARE FORMED, WHICH QUICKLY TURN BLACK. THE WHOLE LEAF CAN DIE WITHIN 1 WEEK.**

Methods of Prevention and Containment of Black Sigatoka

Clifton Wilson

Methods of Prevention and Containment of Black Sigatoka

- Institutional strengthening and technical knowledge base.
- Restriction on the movements of planting material from infected areas



- Transporting germplasm in tissue culture



- Disinfect and wash clothing after entering infected fields. Take the hottest possible showers
- Strict quarantine measures on the movements of fruits and plant parts at the necessary port of entry
- Constant monitoring for the appearance of Black Sigatoka especially on plantain
- Treatment of pallets obtained from areas with Black Sigatoka.
- Use of resistant variety with consumer acceptance

- Eradication: Australia experience.

5

Summary Slide

- Summary Slide



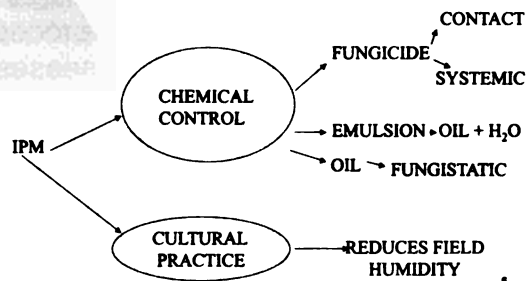
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Summary Slide

- Integrated Pest Management.

7

- Integrated Pest Management.



8

The Effects and Symptoms of Black and Yellow Sigatoka Disease on Banana and Plantain

Janet Conie

The Effects of Black Sigatoka Disease on Banana and Plantain

Bananas and plantain like other plants require an optimum number of healthy leaves in order to produce good fruit yield. Leaves utilize energy from the sun to combine, which is found in the fruits. This process called photosynthesis is severely reduced when yellow or black Sigatoka diseases destroy the leaves. As a result:

- i) Bunches become smaller and lighter.
- ii) The time between shooting and harvest is extended.
- iii) Fruits ripen prematurely in transit and (in severe cases of black Sigatoka) on the trees before harvest.

Mycosphaerella fijiensis is also believed to trigger increased ethylene production, which also hastens the ripening of fruit. At harvest, Internal examination of fruits may be required to detect early signs of ripening. A longitudinal cut will reveal a yellowish glossy pulp near the centre of each finger. In such cases the bunch, hand or box must be rejected. Ripening fruits produce ethylene, which ripen other fruits that may be unaffected by the disease. This also generates the problem of uneven fruit ripening for the distributors. Income to the farmer and the industry is severely reduced by Sigatoka disease as fruit price is based on both quantity and quality. Inconsistent fruit quality is the primary factor contributing to rejection by supermarket costumers. Therefore, the sustainability of export and local markets depends on the efficient control of Sigatoka disease.

Stages in the Development of Black and Yellow Sigatoka Disease Lesions*

<p>Stage 1 A minute yellowish speck, less than 1mm long.</p>	<p>Stage 1 A small yellow speck visible only on the under side of the leaf.</p>	<p>Stage 1 A small yellow speck visible only on the under side of the leaf.</p>
<p>Stage 2 The yellow speck grows to 3-4 mm long x 1 mm wide streak.</p>	<p>Stage 2 Brown streak visible on the underside of the leaf. Later appears on the upper surface as a yellow streak, which progressively turns brown.</p>	<p>Stage 2 Brown streak visible on the underside of the leaf. Later appears on the upper surface as a yellow streak, which progressively turns brown.</p>
<p>Stage 3 The streak begins to broaden and lengthen edges are not well defined and blend in with colour of the leaf. Colour change to lighter.</p>	<p>Stage 3 Streak gets longer, wider and very dark brown in colour. In certain conditions (weak inocula and unfavourable climatic conditions can reach 2-3 cm.</p>	<p>Stage 3 Streak gets longer, wider and very dark brown in colour. In certain conditions (weak inocula and unfavourable climatic conditions can reach 2-3 cm.</p>
<p>Stage 4 The spot has obtained a definite outline with a brown centre and yellow to light brown halo, sometimes with a water-soaked border. Sporodochia differentiation begins and conidial formation is started.</p>	<p>Stage 4 Appears on the underside as a brown spot and on the upper side as a black spot.</p>	<p>Stage 4 Appears on the underside as a brown spot and on the upper side as a black spot.</p>
<p>The dark centre of the spot sinks and the water-soaked halo turns darker brown. (characterized as stage 5 by Meredith 1973).</p>	<p>Stage 5 The elliptical spot is black on the underside of the leaf and is surrounded by a yellow halo with the centre beginning to flatten out.</p>	<p>The elliptical spot is black on the underside of the leaf and is surrounded by a yellow halo with the centre beginning to flatten out.</p>
<p>Stage 5 Spot is fully developed; the sunken centre turns grey and is surrounded by a dark brown or black border sometimes with a yellow halo between the border and the normal green of the leaf.</p>	<p>Stage 6 The centre of the spot dries out, turns grey and is surrounded by a well-defined black ring, which is in turn surrounded by a bright yellow halo.</p>	<p>Stage 5 The centre of the spot dries out, turns grey and is surrounded by a well-defined black ring, which is in turn surrounded by a bright yellow halo.</p>

*(See Annex II for visual)

Typical visible differences between yellow and black Sigatoka

Yellow Sigatoka	Black Sigatoka
<ul style="list-style-type: none"> • Stage 3 is a yellow to light brown streak 	<ul style="list-style-type: none"> • Stage 3 is a very dark brown streak
<ul style="list-style-type: none"> • Spotting usually at the tip of the leaf or in line pattern along the edge 	<ul style="list-style-type: none"> • Spotting is all over the leaf
<ul style="list-style-type: none"> • Spot usually not found close to the mid-rib 	<ul style="list-style-type: none"> • Spots are often found concentrated on both sides of the mid-rib
<ul style="list-style-type: none"> • Initial symptoms: pale yellow streaks on the upper surface of the leaf 	<ul style="list-style-type: none"> • Initial symptoms: reddish brown specks on the lower surface of leaves
<ul style="list-style-type: none"> • Spots appear on 4th to 5th leaf of untreated plant 	<ul style="list-style-type: none"> • Spots may be present on 3rd leaf
<ul style="list-style-type: none"> • Spots are usually yellow to brown 	<ul style="list-style-type: none"> • Spots are dark brown or black especially when wet
<ul style="list-style-type: none"> • Normally do not affect plantains 	<ul style="list-style-type: none"> • Affect plantains as well
<ul style="list-style-type: none"> • Bunches from infected plants (in commercial fields) do not usually ripen (with yellow peel) on trees until they reach a marketable grade 	<ul style="list-style-type: none"> • Bunches from plants infected ripen readily on trees even before marketable grade is reached.

Climatic Influences on Sigatoka Symptom Development

The development cycle of black Sigatoka is influenced by climate-related variations. In favourable weather periods for disease development, there is a proliferation of stage-1 streaks on the leaves. The specks quickly progress to form dead patches and blackening of the leaves without the appearance of discrete lesions. Isolated lesions of stage 5 are seen usually when the inoculum level is low and when climatic conditions are not particularly favourable for rapid spread of the disease.

Correlations have been established between disease development and certain climatic parameters (Foure et al 1992, Gauhl 1989, Ganry and Meyer 1972). Temperature, relative humidity, windiness, precipitation and evaporation, all influence the rate of disease development. However, evaporation and precipitation show the closest correlations and are the most useful climatic data in commercial disease management. Rainfall affects the development of the disease over a period of 1 - 4 weeks after infection. Rapid disease development is seen during periods of high rainfall and low evaporation.

The Effect of Varietal susceptibility and Host-Pathogen Interactions on Symptom Development

To determine the level of susceptibility or resistance in varieties, host reactions are usually evaluated after stomatal penetration and late in the infection cycle. This is due to three main factors associated with resistant varieties:

- i) There is no correlation between incubation time before the appearance of symptoms and susceptibility or resistance.
- ii) Resistance is not related closely to the B genome as was previously thought (Laville 1983). Resistance was found to be present in diploids and triploids carrying only a genome as well as high B component (Tezenas du Montcel 1990).
- iii) There is no sporulation or only slight sporulation in resistant varieties.

Examples

1. **Resistant Variety:** Yangambi km 5 (AAA Ibota)
 - Show blockage of development at stage 1 and 2
 - No asexual sporulation
 - No sexual sporulation

This indicates a hypersensitive response controlled by a single gene, which is useful in conventional breeding programmes. However, it is easily overcome by mutation in the pathogen.

2. **Partial Resistance:** Fougamou (ABB Pisang Awak)
 - Normal but slow development from stage 1 to necrotic stages.
 - Asexual and sexual sporulation
 - Plants have large numbers of functional leaves at harvest.

Usually controlled by multiple genes in other crops but more durable than single gene controlled characteristics.

3. **Susceptible Variety:**
 - Normal and rapid development of from stage 1 to necrotic stages.
 - Asexual and sexual sporulation of fungus is great in favourable weather for disease growth.
 - There are few functional leaves at harvest.

Conclusion

The knowledge of the symptoms and specific effects of black Sigatoka empowers researchers, extension officers and farmers to be able to delay and possibly prevent the entry of the disease in a country. After the inadvertent outbreak, this knowledge is necessary for the identification of the disease at the earliest in order to minimise the impact and implement a local and national plan of action. Symptom recognition is essential for the following reasons also:

- to carry out surveys to determine the extent of spread in order to implement appropriate quarantine measures;
- to determine the intensity of the disease at specific periods or over time;
- for measurement of the results of control strategies in susceptible cultivars, as well as the level of resistance or tolerance in non-susceptible varieties.

References

- Brun J. (1963) La cercosporiose du bananien en Guinee. *Etude de la phase ascosporee du Mycosphaerella musicola Leach*. Thesis, Faculte des Sciences, Universite de Paris - Orsay.
- Foure E. (1994) Leaf spot diseases of banana and plantain caused by *Mycosphaerella musicola* and *M. fijiensis*. *The Improvements and testing of Musa: a Global Partnership*. Proceedings of the first global conference in Honduras. (DR. Jones ed) INIBAP 37 - 46.
- Foure E. & Moreau M. (1992) Contribution a l'etude epidemidogique de la cercosporiose noire dans la zone bananiere du mocengo au Cameroon de 1987 a 1989. *Fruits* 47 (1), 3-16.
- Ganry J & Meyer JP (1972) La lutte controlee la cercosporiose aux Antilles. Bases climatique de l'avertissement. *Fruits* 27 (10), 665-676.
- Laville E. (1983) Les cercosporoses du bananier et leurs traitements. Comportement des varietes. *Fruits* 38 (3), 147-151.
- Tezenas du Montcel H. (1990) The susceptibility of various cultivated bananas to Sigatoka diseases. *Sigatoka Leaf Spot Diseases of Bananas: Proceedings of an international workshop held in San Jose, Costa Rica (1989)* 272-286.

DISEASE FORECASTING & MONITORING

Phillip Chung

The project proposed to base its control mode on a preventative basis, hence the need for disease forecasting and monitoring. An effective forecasting system allows for execution of control methods at the right time (only when it is necessary). After analysis of environmental and biological data, for instance, if one could forecast accurately when conditions will lead to an increase or decrease of Sigatoka, then spraying could be scheduled accordingly.

The main objectives of the forecasting system are:

- Prevent a Sigatoka Outbreak
- Reduce Input and Consequently Costs
- Reduce Environmental Pollution

BIOLOGICAL FORECASTING

There are two biological forecasting systems:

Youngest Leaf Spotted [Y.L.S]

This is a simple method of disease assessment. Approximately twenty-five (25) mature 'non shot' plants are assessed per acre per week. The youngest fully opened leaf with ten (10) or more spots are recorded (see figure 1). A Y.L.S of at least eight (8) is required for commercial banana production.

This method of assessment only takes into account the latter stage of the disease (spots stage), which are easily visible. However, the disease has already created leaf damage.

Cronshaw

This is a more rigid way of assessing Sigatoka 'flare up' and is sometimes referred to as early disease infection indices. The disease will be identified in the early stage and hence preventative measures can be taken. Unlike Y.L.S, only ten (10) plants are assessed per acre per week.

In Cronshaw, the most advanced stage of the disease is recorded on the first five (5) leaves of the followers (suckers)

The Five Stages of Yellow Sigatoka Development

Stage of Sigatoka Development	Signs & Symptoms
Stage I	Small yellow fleck (1 x 1mm. Approx.) on the upper leaf surface.
Stage II	Yellow streak (1 x 4mm approx.) on the upper leaf surface.
Stage III	Streak broadens and lengthens and becomes mottled rusty brown colour. Now visible on both surfaces of leaf.
Stage IV	Spot dark brown to black surrounded by yellow halo, slightly sunken center.
Stage V	Spot dries out at the center becomes light brown to pale gray, usually surrounded by a black border and a yellow halo.

The total for the first five (5) leaves on the plant is then summed. This assessment method is carried out on ten (10) plants so that a mean or average can be found.

The method is summarized as follows:

Leaf Number	Multiplication Factor
1	5
2	4
3	3 x most advanced spot stage of
4	2 which there are more than 10
5	1 present
	TOTAL

Find average of ten (10) plants assessed. A typical record sheet that can be used follows.

SIGATOKA DISEASE FORECAST SYSTEM

Station: _____

Year: _____

Week No.	YLS Avg.	Cronshaw Value	Rain-fall (mm)	E	E _w	A	D	SDT	LWS	NWS	F	Remarks
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												

Where *E* = weekly evaporation totals

E_w = weighted evaporation

$$= \frac{E_n + E_{(n-1)}}{2}$$

n = week number

A = Factor which varies according to climate, soil type and health of the plantation

D = Number of days between spray cycles

$$= \frac{E_w \times 7}{2}$$

STD = Speed of development totals. Daily maximum and minimum temperatures are used to determine the coefficient of disease development (Ganrey and Meyer, 1972).

LWS = Last week sprayed

NWS = Next week sprayed = (*D*/7) + *NWS*

F = Fungicide used

MANAGEMENT OF 'HOT SPOTS'

Marina Young

- **What is 'HOT SPOT' and what is not?**

- **Identification of cause factor(s)**

- *microclimate*
 - *sanitation*
 - *drainage problems*
 - *coverage problems*
 - *status of nutrition (soil & leaf analysis)*
 - *resistance and/or reduced sensitivity;*
 - *other factors*

- **Disease monitoring**

(YLS & Cronshaw) + EVAPORATION

- **Chemical control**

- *use of ground spraying with protectant fungicide in between aerial applications*

- **Consistency of ground spraying!!!**

- **Effectiveness of aerial applications versus ground spraying for Black Sigatoka control**

- *Leaf coverage (upper/ underside; volatilisation of fungicide / remaining on the plantation floor)*

Fungicide Strategies for Efficient, Economical Control and Resistance Management

Janet Conie

Chemical Control

- ✓ **Chemicals are used to compliment cultural practices, which are essential for the reduction of black Sigatoka disease inoculum levels. Fungicide application in isolation cannot effectively control the disease at the most economical cost.**

Fungicides are sprayed by aircraft, tractors or backpack mist blowers. Ground applications are suitable for small plantations and those situated on hilly terrain or where aircraft prove to be inaccessible (for example under power lines). Turbo Jet aircraft fitted with geographical positioning systems (GPS) and guided by satellite information are commonly used in Central America. These state of the art equipment guarantee precision spraying. In Jamaica 80% of the export plantations are sprayed by aircraft without GPS. The remaining 20% is sprayed by backpack sprayers.

Fungicides

Protectants

Protectant or contact fungicides are not absorbed by the plant and act by killing on contact. They have a multi-site mode of action in the fungus, reacting with the thiol (SH) group of enzymes. The protectants that are suitable for Sigatoka disease control are the dithiocarbamates and chlorothalonil. Chlorothalonil and specific formulations of dithiocarbamates (dry flavable (DF) and dry granular (DG)) can only be applied in water. Other formulations of dithiocarbamates can be applied in emulsions (oil soluble (OS) and suspension concentrates (SC)). Dithiocarbamates are applied at 1000-1500 g/ha.

Chlorothalonil is incompatible with oil and causes a superficial phytotoxic reaction on the leaf. This reaction is also evident when sprayed before or after oil applications. Chlorothalonil is sprayed at 1000-2000 g/ha.

Systemics

Systemic fungicides are absorbed by the plants and are able to kill the pathogen within the leaf after infection. They have specific modes of action and consist of the benzimidazole, morpholine, triazole and strobilurin groups of fungicide.

a) **Benzimidazoles**

Benzimidazoles stop microtubule assembly in mitosis and meiosis, thus interfering with cell division. Benomyl and thiophanate methyl are used at rates of 1400 -1500 g/ha.

b) **Morpholine**

Tridemorph is the only morpholine currently being used to control Sigatoka disease. Fenpropimorph appears to have improved efficacy. Morpholines are only partially systemic as leaf penetration is limited. Tridemorph and fenpropimorph have multi-site action at two sites and prevent ergosterol synthesis in the fungal cell membrane. The active ingredient of the fungicide is applied at 450 g/ha.

c) **Triazoles**

Triazoles inhibit a cytochrome, which catalyses the C-14 demethylation reaction in the ergosterol biosynthesis pathway. The triazoles are called demethylation inhibitors or DMI. There are several fungicides in this group of which propiconazole is the first. Others are flusilazole, fenbuconazole, hexaconazole, cyproconazole, bitertanol, epoxiconazole, fenbuconazole and bromuconazole. They demonstrate differences in efficacy and movement in the leaf. Propiconazole moves towards the margins of the leaf while bitertanol and fenbuconazole concentrates near the midrib. This explains the concentration of Sigatoka lesions in specific regions when particular triazole fungicides are used. Cross-resistance exists among triazoles. This means that fungal populations found to be less sensitive to a particular triazole will also have similar low sensitivity to the other triazoles. Triazoles are applied in oil or emulsion at a rate of 100 g/ha of active ingredient, with the exception of bitertanol, which is applied at 150 g/ha.

d) **Strobilurins**

The strobilurins are the newest fungicide group. They occur naturally in the Agaricaceae mushrooms. The natural product is physically unstable.

The artificially manufactured products (e.g. methoxyacrylates) are stable and interfere with respiration in the fungus by binding to cytochrome b and disrupting electron transfer from cytochrome b to c. Strobilurins azoxystrobin and teflorystrobin are applied at 100 g/ha of active ingredient in oil or oil water emulsion.

Table 1. Fungicides approved for use to control Black Sigatoka disease

FUNGICIDE GROUP	ACTIVE INGREDIENT	TRADE NAME
<i>Protectants</i>		
Dithiocarbamates	mancozeb	Mancozeb [®]
		Manzate [®]
		Zancozeb [®]
		Vandozeb [®]
		Dithane [®]
		Zineb [®]
Chlorothalnil	chlorothalnil	Bravo [®]
		Daconil [®]
<i>Systemics</i>		
Benzimidazole	benomyl	Benlate [®]
	thiophanate-methyl	Sigma [®]
		Topsin [®]
Morpholines	tridemorph	Calixin [®]
	fenpropimorph	Volley [®]
Triazoles or demethylation inhibitors (DM1)	propiconazole	Tilt [®]
	flusilazole	Punch [®]
	fenbuconazole	Indar [®]
	bitertanol	Baycor [®]
	tebuconazole	Folicur [®]
	hexaconazole	Anvil [®]
	cyproconazole	Alto [®]
	bromuconazole	Vectra [®]
	epoxyconazole	Opal [®]
Strobilurins	azoxystrobin	Bankit
	teflorystrobin	Tega

Fungicide Strategies

Analysis of a number of factors must be considered when making a decision on the time and type of fungicide treatment to be applied. These factors include:

- a weekly analysis of disease data from plants on each farm,
- the rate of leaf emission,
- weather data on a weekly basis and
- the sensitivity of the local fungal population.

Application of Fungicide Based on a Disease Forecasting System.

This forecast system can only be successful when all fungicides (and particularly the systemics) are at optimum potency. The system also works best in regions where climatic conditions are not always favourable for diseases development. The forecasting system has been very successful in the French Antilles. It is based upon regular assessments of temperature, evaporation and early infection stages of disease symptoms. The method was modified and used in Central America, Cameroon, Columbia and Jamaica. It was used successfully to schedule spray applications commercial plantations in all named regions but subsequently failed in Central America when fungal populations resistant to the systemic fungicides developed. Details of the methodology of the Jamaican Sigatoka disease forecast system is given in Conie and Dixon 1992.

The procedures used in Central America and the Cameroons was published by Marin and Romero 1992 and Fouré 1990.

The system of detecting early warning or predicting disease outbreaks allows for application of fungicides only when necessary. Therefore the number of applications; consequent cost and environmental pollution, are reduced. Other methods of disease forecasting for black Sigatoka were developed by Chuang and Jager (1987), Wielemaker (1990), Bureau (1990) and Lesest et al (1998).

Fungicides Applications Based on Crop Growth and Weather Conditions (Calendar-based System)

The unavailability of systemic fungicides (mainly due to disease resistance to benomyl and propiconazole) dictated an increased use of protectants. Protectant fungicides must be applied in alternation or in cocktail mixtures with systemics. It must also be safe guarded that contact fungicides are sprayed on schedules that ensure that most unfurling, newly opened and youngest leaves are covered. Schedules close to the rate of leaf emergence are critical during weather conditions that are favourable for disease development. Leaf emission varies with temperature, crop nutrition and soil type and drainage. In regions where disease

sensitivity to systemic fungicides is high, protectant fungicides are not recommended during the high rainfall periods.

This so-called calendar based method should never be fixed but also be dependent on weather and disease assessment data.

Integrated Approach to Developing Fungicide Strategy

An integration of the forecast system and those based on crop growth, weather conditions and efficacy of the fungicides, is ideal for scheduling fungicide applications. Decisions taken that are based on many factors are less likely to be incorrect. Further, the data collected for each parameter will provide backup or control check for the others.

Although collected individually, all data upon which fungicide strategy will be based must be presented together in weekly tabular and graphical formats. An example is appended. Decisions to spray are based increasing trends of the parameters, which indicate favourable disease conditions. Thresholds are not relied upon.

Fungicide Resistance Management

The economic consequence of fungicide resistance can result in the number of application being 2 - 3 times more than normal. The social repercussion is that farmers in the Caribbean would not be able to carry the associated cost without consistent external funding. Caribbean banana exportation would be curtailed. Also, the environmental impact of the exposure to greater volumes and frequency of contact fungicides can be detrimental to the ecosystem.

Therefore, concerted strategies must be employed in countries or specific areas where black Sigatoka has spread recently, or where shifts in systemic fungicide sensitivity have not yet occurred. Baseline sensitivities of local pathogen populations to different groups of fungicides must be established and regularly monitored in order to detect early changes.

Fungicide sensitivity monitoring must be complimented by appropriate fungicide application strategy. Common strategies employed to guarantee fungicide efficacy and delay or prevent resistance in areas where systemic fungicide sensitivity is still high are as follows:

Alternate fungicides with different modes of action in single applications only (never consecutive or "in blocks").

- 1) Limit the use of fungicides such as strobilurin, demethylation inhibitors DMI and bezimidazoles that are at risk of developing resistance.
- 2) Apply systemics for preventative control only and not as the main means to counteract loss of disease control.
- 3) Systemics applied in cocktail with protectants lowers the disease intensity significantly and is a means of preventing or delaying the onset of disease resistance. The dose rates of the individual fungicide must be applied at full strength. However, cocktails will not reduce the frequency of resistant strains once they have become established. Cocktails reduce the overall population thus limiting sexual recombination and the flow of resistant genes in the population.
- 4) Allow a period of not less than three months free from strobilurin use and DMI applications.
- 5) When fungal sensitivity to these products is reduced to the critical threshold (fungicide sensitivity monitoring), the products should be withdrawn totally. Temporary withdrawal of propiconazole for six months made no significant effect in reducing resistant population in Costa Rica (Romero in Jones 2000) similar results were seen in Jamaica. They can be re-introduced only when sensitivity has been significantly increased. Total withdrawal of propiconazole has shown effective results in 1-2 years. This reduces the selection pressure in resistant populations. Substitutes of tridemorph and protectants are recommended.
- 6) Use a rate of oil of no less than 10L/ha to enhance the activity of systemic fungicides.
- 7) Never use reduced rates of systemic fungicides.
- 8) Maintain all cultural practices that will reduce the amount of inoculum.

Example of strategies used in Jamaica is given in the Tables (2 and 3) below. The proposed 29 applications are reduced to 18 and 26 applications in different areas with the super imposition of data analyses of climatic and disease parameters.

Table 2. Twelve Month Chemical Management Programme for Black Sigatoka

Control and the Prevention of Fungicide Resistance

TIME OF YEAR	WEATHER CONDITIONS	FUNGICIDE	APPLICATION BASE	APPLICATION INTERVAL (days)
JANUARY		Calixin	Emulsion/Oil	12-15
		Benlate*	Emulsion/Oil	12-15
		Calixin	Emulsion/Oil	12-15
	DRY?	Benlate*	Emulsion/Oil	12-15
		Calixin	Emulsion/Oil	12-15
MARCH		Manzate	Water	8-10
		Bravo	Water	8-10
APRIL		Calixin	Oil/Emulsion	12-15
	RAIN expected	Tilt	Oil/Emulsion	15-18
MAY		Benlate	Oil/Emulsion	12-15
		Calixin	Oil/Emulsion	12-15
	WET?	Benlate	Oil/Emulsion	12-15
		Calixin	Oil/Emulsion	12-15
JUNE		Bankit	Emulsion	15-18
JULY		Benlate*	Emulsion	12-15
		Calixin	Emulsion	12-15
	DRY	Benlate*	Emulsion	12-15
		Manzate	Water	8-10
AUGUST		Bravo	Water	8-10
SEPTEMBER	RAIN expected	Tilt	Oil/Emulsion	15-18
		Benlate	Oil/Emulsion	12-15
OCTOBER		Calixin	Oil	12-15
		Benlate	Oil	12-15
	WET	Calixin	Oil	12-15
		Benlate	Oil	12-15
NOVEMBER		Bankit	Emulsion	15-18
DECEMBER	DRY	Calixin	Emulsion/Oil	12-15
		Benlate	Emulsion/Oil	12-15
TOTAL NUMBER OF APPLICATIONS :	Bankit 2 Tilt 2 Calixin 10 Benlate 9 Manzate 2 Bravo 2 Total 28	* Substitution of these applications with protectants is appropriate when disease levels are low. This will reduce the number of Benlate applications to 6 for better resistance management.		

Table 3. Sigatoka Management Strategy for Fields with Fungicide Resistance

Week No.	Resistance to Benlate	Resistance to Benlate & Tilt	Micro-climate
1	TILT	BANKIT	COLD & DRY? (WET)
3	CALIXIN / MANZATE	CALIXIN / MANZATE	
5	MANZATE	MANZATE (CALIXIN)	
7	CALIXIN	CALIXIN (TILT)	
9	MANZATE	MANZATE (BRAVO)	
11	CALIXIN	CALIXIN	
13	TILT	BRAVO	
15	CALIXIN / MANZATE	CALIXIN / MANZATE	WARM & DRY
17	CALIXIN	CALIXIN	
18	MANZATE	MANZATE	
20	CALIXIN	CALIXIN	
21	CALIXIN / MANZATE	CALIXIN / MANZATE	HOT & WET?
23	BANKIT	BRAVO	
25	CALIXIN	CALIXIN	
27	BRAVO	BRAVO	
29	CALIXIN	CALIXIN	
31	BRAVO	BRAVO	HOT & DRY
32	CALIXIN / MANZATE	CALIXIN / MANZATE	
33	TILT	BANKIT	
35	CALIXIN	CALIXIN	
37	CALIXIN / MANZATE	CALIXIN / MANZATE	HOT & WET
38	TILT	BANKIT	
40	BRAVO	BRAVO	
42	CALIXIN	CALIXIN	
44	BRAVO	BRAVO	
46	CALIXIN	CALIXIN	
47	BANKIT	BANKIT	COLD & WET
50	CALIXIN	CALIXIN	
52	BRAVO	BRAVO	

BANANA BOARD RESEARCH DEPARTMENT (2001).

References

Chuang, T.Y. and Jeger, M.J. (1987). Predicting the rate of development of Black Sigatoka (*Mycosphaerella fijiensis* ver. *difformis*) disease in southern Taiwan. *Phytopathology* 77 1542-1547.

Conie, J.E. and Dixon, J.A. (1992) Improved Sigatoka Management: One factor to Increase Productivity for Banana Farmers in Jamaica. *Report of the Research Department Banana Board (1987-1994)* 11-30

Jones, D.R. (2000) *Disease of Banana, Abaca and Enset*, CABI Publishing 543 p.

Foure, E. (1990) *La lutte integree contre le cercosporiose noire des bananieres*

Au Cameroon. L'avertissement biologique et son Evolution de 1985 a 1988
In: Fullerton, R.A. and Stover R.H. (eds) *Sigatoka Leaf Spot Diseases of Bananas, Proceedings of an International Workshop* held in San Jose, Costa Rica, March 28 - April 1, 1989, INIBAP, Montpellier, France pp, 124-134.

Lescot, T, Simonot, H, Fages, O. and Escalant, J.V. (1998). Developing a biometerological forecasting system to control leaf spot disease of plantains in Costa Rica. *Fruits* 53, 3-16.

Marin, D.H. and Romero R.A. (1992) El combate de la Sigatoka negra. Boletin No. 4, Departamento de Investigaciones, CORBANA, San Jose, Costa Rica, 22p.

The Variability of Sigatoka Pathogens and Climatic Conditions on Different Territories and the Necessity for Appropriate Control Strategies and Research (Local and International Update)

Marina Young & Janet Conie

- **GENETIC VARIATION OF *M.fijiensis* EXISTS ON A MICRO- AND MACRO-SCALE (Nigeria, Muller *et al.* (1997)):**

Variability occurred within:

- / one lesion
- between lesions on one plant and
- between plants and cultivars as well as
- between geographical locations

RESEARCH NEEDED:

-ACCURATELY ESTIMATE VARIABILITY OF *M. fijiensis*
(If different banana-producing areas have only one or several epidemiological units)

- at plant
- field
- district
- country
- region: levels

Methods of research:

- Use of molecular markers and
- Undertaking inoculations tests to determine pathogenic differences

Black Sigatoka is a disease of global proportions. The genetic diversity of the fungus causing it, *Mycosphaerella fijiensis*, is very high in its centre of origin in Asia, especially in Philippines and Papua New Guinea. As the pathogen move from this region to Africa, America and most recently the Caribbean, some of this genetic diversity has been lost. However, an important proportion still remains, and knowledge of extent and distribution of this remaining variability provides important information to aid breeding and the management of disease resistance. For this reason, CATIE and CIRAD are conducting a study, with INIBAP support.

The study was initiated with the objectives to evaluate pathogenic variability of Sigatoka in the Latin America and Caribbean region in order to understand the mechanism of pathogen resistance, cross-resistance as well as origin of black Sigatoka inoculum in various countries.

M. fijiensis samples from Honduras, Costa Rica, Panama, Colombia, Cuba, Jamaica and Dominican Republic were analysed with highly scientific methods using eight cleaved amplified polymorphic sequences (CAPS), as a molecular markers. Prior to that mono-spore isolates were trapped on the agar media. After culturing the fungus, DNA was extracted and multiplied by polymerase chain reaction (PCR).

Initial results show that genetic diversity of *M. fijiensis* in Honduras and Costa Rica is relatively high compared to populations elsewhere, suggesting that the pathogen first entered continent in this area.

Highly diverse pathogens have the ability to develop resistance

A high level of genetic differentiation was detected between most of the populations analysed indicating that gene flow is limited. Meanwhile there is sufficient differentiation between populations in the Caribbean islands to support a theory that more than one introduction occurred from Latin America.

It is likely that the disease, therefore, has spread in the region through infected material and/or through restricted dispersal of ascospores.

Research findings presented were very interesting and sometimes unexpected. Populations of black Sigatoka isolates from Honduras, Costa Rica and Jamaica were closely related. However, isolates from Cuba and Jamaica were distantly related, proving the point that black Sigatoka was not introduced to Jamaica from Cuba, but from Honduras or Costa Rica (Appendix 2).

- The origin of black Sigatoka in other countries needs more verification;
- The cross-resistance (the ability of pathogen to develop resistance to all the fungicides within one chemical group, or easily gain resistance to other

chemical groups) of *M. fijiensis* was proven, however it is not 100% cross-resistance.

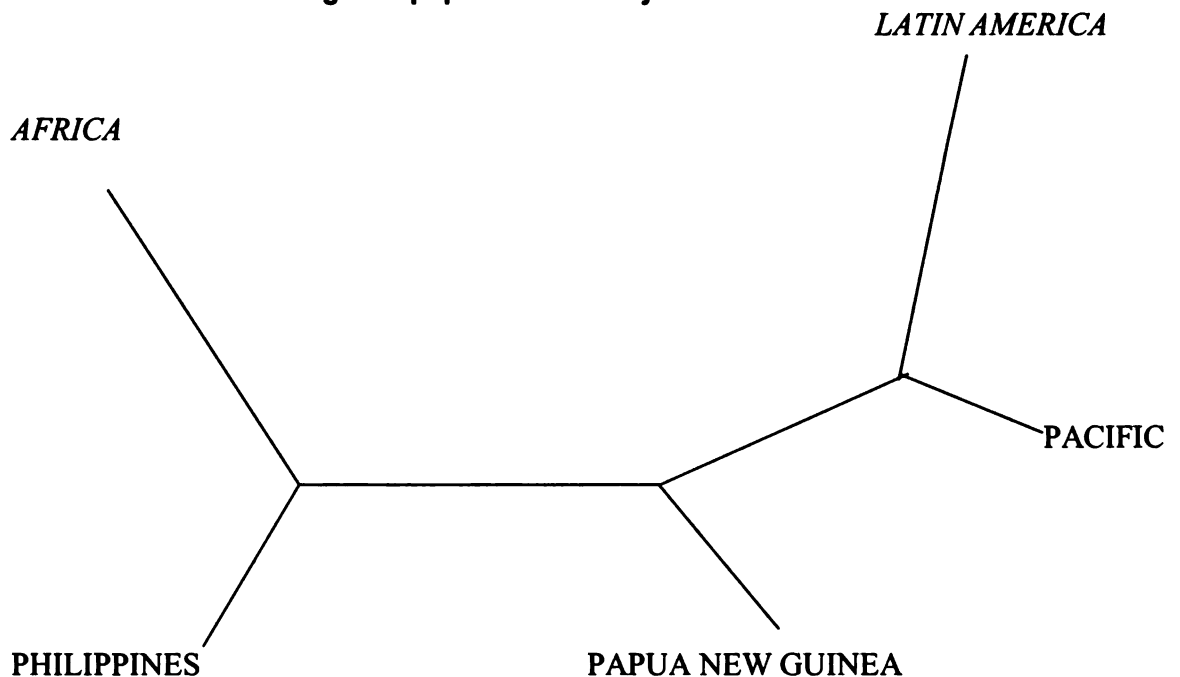
- Overall, incidence of lack Sigatoka is higher than in the past
- ELISA (enzyme-linked immunosorbent assay) method remains as very reliable indicator of the amount of Sigatoka inoculum. However the method is not used widely at the present.

References:

1. Population structure of *M. fijiensis* in the American Tropics, paper presented by Galileo Rivas, CATIE, Guapiles, Costa Rica at the II International Seminar on Control of black Sigatoka, Jan Jose, Cost Rica, April 30th – May 3rd, 2001.
2. Genetic diversity of a destructive pathogen: genetic differentiation between *M. fijiensis* populations in Latin America and the Caribbean. Banana & Plantain Networking, Annual Report 2000, INIBAP, page 34.
3. Diseases of Banana, Abaca and Enset. Edited by D.R. Jones. 2000. CABI Publications, New York, NY 100016, USA

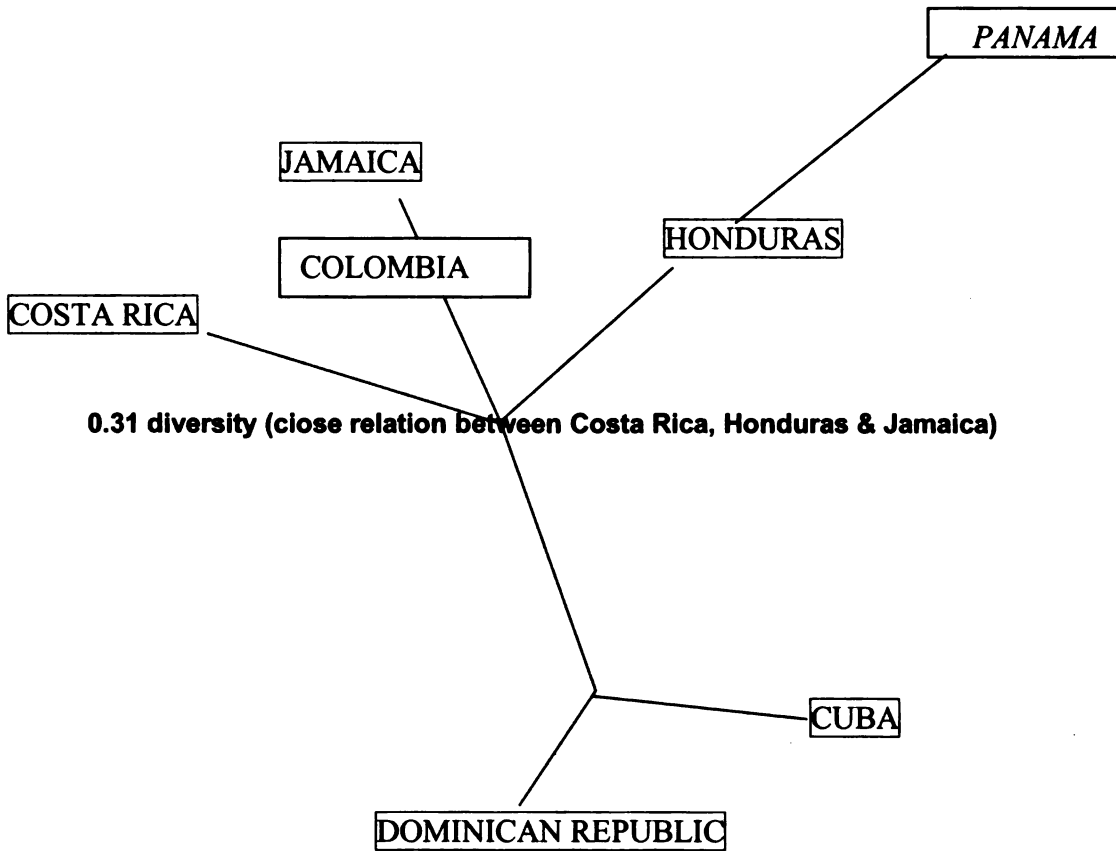
Appendix 1.

Genetic structure of the global population of *M. fijiensis*



Appendix 2.

Genetic differentiation between populations of *Mycosphaerella fijiensis* in Latin America and the Caribbean, helping to trace the pathway of the black Sigatoka. (The length of the line is proportional to the degree of genetic differentiation).



0.31 diversity (close relation between Costa Rica, Honduras & Jamaica)

Close relation between Cuba & Dominican Republic.

Distant relation in Black Sigatoka diversity between Jamaica & Cuba

Introduction to Fungicide Sensitivity Monitoring (FSM)

Janet Conie & Marina Young

It has become a norm to associate Sigatoka disease of banana with the problem of fungicide resistance. The number of chemical groups available for the disease control remains limited, and the mentality of only chemical control versus Black Sigatoka is still dominant. In the countries where resistance to one or more chemical groups occurred, the cost of Sigatoka control continues to rise. Attempts to bring the cost down, forcing the farm owners to implement disease control strategies, only compound the problems, pushing the 'button' of selective pressure further.

It is critical that fungicides used in Sigatoka disease control remain extremely effective. Without potent chemicals, the cost of production would increase significantly and place the Banana Industry in great jeopardy. Considering the fact that only a limited number of chemical fungicide groups are available for leaf spot control, the chemicals have to be used wisely in order to avoid or delay the development of fungicide resistance.

The great advantage is that over the years the local industry has developed and followed its own guidelines of Sigatoka control strategies, which once again proved to be effective. It is also an advantage to have knowledge of bad decisions in Sigatoka control made in other banana producing countries, and the opportunity to avoid falling in the similar path.

Fungicide Sensitivity Monitoring (FSM) is a laboratory procedure for the determination of Sigatoka fungal sensitivity to a particular chemical group of fungicides, as much as to a single fungicide. Results of the tests are specific to a particular farm or group of the farms in the same area and provide the ability to detect early changes in fungal sensitivity over a period of time.

The procedures for FSM are carried out in accordance with the protocol developed by the Fungicide Resistance Committee (FRAC), North American Group.

HOW DOES FUNGICIDE RESISTANCE DEVELOP?

- **Too frequent use of single site inhibitor:**
block treatment

- more than recommended number of applications per year
- poor agricultural practices causing high inoculum and disease levels

- Exposure of the fungus to minute or excessive quantities of fungicide:

- below recommended dose rates
- too high dose rate
- poor coverage or patchy spraying
- improper mixing of fungicide(s)

- Poor chemical management strategy

FUNGICIDE RESISTANCE

Factors:

- GENETICAL MATERIAL
- MONOCULTURE
- SUSCEPTIBLE VARIETIES
- FERTILIZATION

(high dosages of nitrogen)



Needs: NECESSITY OF FUNGICIDE APPLICATIONS



Limitations:

LIMITED NUMBER OF CHEMICAL GROUPS AVAILABLE FOR CONTROL OF SIGATOKA AND CONTROL STRATEGIES RECOMMENDED IN THE PAST



FUNGICIDE RESISTANCE

RESISTANCE TO *M. fijiensis*

BIOLOGICAL FACTORS

- Variability of pathogen

- Type of reproduction / number of sexual cycles (7 or more per year)
- Type of sporulation (conidiospores/ ascospores)
- Monoculture vs. annual crop
- Susceptibility of cultivars
- Number of fungicide applications

REVIEW OF FRAC MEETINGS & RECOMMENDATIONS

Resistance of Sigatoka to fungicides is one of the major challenges faced by the banana producers worldwide.

The FRAC (Fungicide Resistance Committee) has its origin in development of fungicide resistance. In order to deal with issue chemical manufacturers and researchers formed a committee, which would provide recommendations for the management of resistance. Importantly, those recommendations were sometime compromised between the chemical companies (whose objectives are to maintain high volumes of pesticide sale) and researchers (whose intentions are to avoid, or delay development of resistance by the optimising the use of pesticides). It should be pointed out that FRAC recommendations should never be accepted as the only rule to follow, but rather as guidelines. Recommendations were produced sometimes without full consensus of both parties involved, and often the opinions of the chemical companies were dominant.

Based on the information presented below, it can be clearly seen, that because of compromises agreed on at the FRAC meetings, recommendations that were implemented did not effectively stop further development of resistance.

1st FRAC Meeting (1987)

The meeting summarized the present status of resistance:

Fungicide *benomyl* was introduced in 1972, resistance developed in 1976. It was recommended that Tilt (*propiconazole*) (introduced in 1987) could be applied in 2-3 consecutive applications.

2nd FRAC Meeting (1990)

Due to development of Sigatoka resistance to propiconazole, 3-4 months Tilt-free period and a total of 4-6 triazoles cycles per year were recommended. FRAC

also opposed use of DMI's (dimetholate inhibitors, including Tilt) for the spraying of soil in the banana plantations.

Costa Rica successfully introduced use of ELISA method for the monitoring of Sigatoka population and forecasting.

Problems with the standardization of fungicide sensitivity monitoring methodology were outlined. ED 50 was recommended for the inhibition percentage of germ tube length.

3rd FRAC Meeting (1993)

The situation for the period of 1990- 1992 was assessed. Further reduction in sensitivity to triazoles was acknowledged. Overall, approximately after 4 years of abusive use of fungicides resistance developed.

Status of Fungicide Resistance (1993)

Benlate (<i>benomyl</i>) resistance	Triazoles resistance
Belize, Guatemala, Honduras, Costa Rica, Mexico, Guadeloupe and Martinique. No <i>benomyl</i> resistance was detected in the English speaking Caribbean.	Belize, Guatemala, Honduras, Costa Rica No resistance detected in Panama, Cameroon, Martinique and Guadeloupe

FRAC recommended use of fungicide mixtures, and necessity to alternate different chemical groups of fungicides instead of block treatments.

- use of contact fungicides was not yet recommended;
- use of full dose rates was emphasized;
- number of triazoles mixtures (cocktails of triazoles) was recommended as not more than 10 /year;
- use of Calixin was restricted to not more than 12 cycles / year;
- use of *benomyl* was recommended at 280 g. a.i./ hectare (in stead of 113g. a.i/ hectare)

Limitations of the EC50 values used in FSM (fungicide sensitivity monitoring) procedures were discussed. Method of inhibition at the discriminatory doses (0; 0.01; 0.1 and 1.0 pm) was recommended.

4th FRAC Meeting (1996)

By 1996 the following strategies of Sigatoka control in Costa Rica were used:

8-10 cycles of DMI's (mostly triazoles);
10-14 cycles of tridemorph
1-3 cycles of benzimidazoles

Some of the farms in Costa Rica with resistance problems were using up to 36-cycles/ year. Because of high frequency of fungicide applications, forecasting system was no longer used. Level of propiconazole sensitivity was very low. Cross-resistance was demonstrated for triazoles.

FRAC recommended strategy similar to the previous meeting, with exception that different DMI's can be used without increasing the number of cycles, since all of them can be considered as one chemical group. Insufficiencies in the FSM methods were also discussed.

5th FRAC Meeting (1998)

FRAC reviewed developments with Sigatoka resistance for the period of 1996-1997, and summarized all five compounds available for Sigatoka control (triazoles, benzimidazoles, morpholines, dithiocarbomates / chlorothalonil [contacts], and newly introduced strobilurin).

Up to date, efficacy of strobilurin Bankit (a.i. *azoxystrobin*) was excellent, and method of FSM was improved. At that time, total of 8-cycles/ year of Bankit were recommended. FRAC agreed that recommendations for the use of triazoles and benzimidazoles should remain the same.

6th FRAC Meeting (2000)

The situation on the use of the fungicides was summarized as follows:

- For the period of 1998 2000, DMI's mixtures with contacts were highly used;
- No resistance or major shifts in to Calixin sensitivity detected to date;
- No reverse in *benomyl* sensitivity detected;
- Sensitivity of Sigatoka to Bankit was high.
- Resistance to Bankit was detected on one farm in Costa Rica.

Sensitivity to fungicides: current status

Status of Sigatoka sensitivity to various triazoles fungicides in Latin America

Country	Fungicides		
	Propiconazole	Difenoconazole	Azoxystrobin
Costa Rica	Further decrease in sensitivity	Shift in resistance	Development of resistant strain detected on one farm. Same farm has resistance to propiconazole.
Country	Fungicides		
	Propiconazole	Difenoconazole	Azoxystrobin
Panama	Shift in resistance detected. However, resistance level remains the same for several years	High sensitivity	High sensitivity
Colombia & Ecuador	Sensitivity parameters are good and stable	High sensitivity	High sensitivity

Based on the information presented by Suzan Knight, SYNGENTA, Costa Rica.

Management of fungicide resistance for azoxystrobin in future

(Based on the SYNGENTA's recommendations):

Bankit must not be used on the farms where resistance to other fungicide groups was detected

Recent cases of development of Sigatoka resistance to *azoxystrobin* occurred on the farm where resistance to both (*benomyl* & *propiconazole*) was detected.

Recent research findings are proving that *resistant populations carry resistance gene known as G143A, which predispose development of resistance to other chemical groups. However, there are other undiscovered mechanisms responsible for resistance*

- Only 4 cycles per year are recommended (in stead of 8 cycles recommended earlier)
- Only curative use of Bankit is recommended
- Bankit must be used at full dose rate recommended
- Do not use Bankit in the dry periods

Management of *benomyl* resistance in the future

- Resistance to *benomyl* is presently detected at 25 ppm (10 ppm is usually used as threshold concentration for FSM)
- *Benomyl* resistance is not reversible.
- there should be no use of *benomyl* in consecutive cycles, or block treatment;
- not more than 6 cycles of *benomyl* per year should be applied (SYNGENTA)
not more than 4 cycles per year (DuPont)
- use *benomyl* in fungicide mixtures
(when *benomyl* is used in mixtures with contact fungicides, no further shifting in resistance occurs.)

FUNGICIDE SENSITIVITY MONITORING - *tridemorph* (Calixin®) STATUS

After introduction of Calixin to the market in 1980s, there are no indications of major shifting in sensitivity of Sigatoka to *tridemorph*. FSM for *tridemorph* was initiated only in 1984 (BASF).

R. Romero of Costa Rica believes that there is a slight shifting in sensitivity (but not substantial)

After 25 years on the market, *tridemorph* has average 45 % of germ tube length inhibition at 1.0 ppm.

Calixin is going to remain as one of the major chemicals for Sigatoka control.

PREVENTION, DELAYING & MANAGEMENT OF FUNGICIDE RESISTANCE (strategy used in Jamaica)

- Most important is to DECREASE SIGATOKA POPULATION!!!
1. Sanitation [de-leafing, pruning etc.] is extremely IMPORTANT!!
2. Chemical control strategy:

IN JAMAICA SIGATOKA MANAGEMENT STRATEGY CONSISTS OF THE ALTERNATION OF THE BENZIMIDAZOLE AND TRIDEMORPH; AND APPLICATION OF TRIAZOLES (propiconazole) AT THE BEGINNING AND THE END OF RAINY SEASON. CONTACT FUNGICIDES ARE USED ONLY IN THE DRY PERIOD.

- ALL SYSTEMIC CHEMICALS MUST BE USED AS PREVENTATIVE (NOT CURATIVE) TREATMENT
- EACH FUNGICIDE (= CHEMICAL GROUP) APPLIED AS A SINGLE TREATMENT ALTERNATED WITH OTHER CHEMICAL GROUP (NO BLOCK TREATMENTS)
- ALL FUNGICIDES ARE USED AT THE FULL DOSE RATES
- HIGHLY POTENT SYSTEMIC PRODUCTS ARE USUALLY APPLIED BEFORE AND AFTER THE MAJOR RAINY PERIODS (will be varying from country to country) IN ORDER TO DECREASE THE SIGATOKA POPULATION PRESSURE
- IT IS IMPORTANT TO ENTER THE RAINY PERIOD WITH GOOD SIGATOKA CONTROL!
- DURING THE WET PERIODS SYSTEMICS ARE USED IN THE STRAIGHT OIL BASE APPLICATIONS IN ORDER TO ENSURE THEIR MAXIMUM EFFICACY
- NOT MORE THAN 4 TRIAZOLE CYCLES PER YEAR SHOULD BE APPLIED (DURING EXCEPTIONALLY WET YEAR UP TO 6 TRIAZOLES CYCLES)
- NOT MORE THAN 2-3 AZOXYSTROBIN CYCLES PER YEAR IS RECOMMENDED
 - PRESERVATION OF POTENCY (RECENT RESEARCH FINDINGS)
 - COST FACTOR
 - ADEQUATE STATUS OF SIGATOKA SENSITIVITY ON MOST OF THE EXPORT FARMS
- USE OF FUNGICIDE COCKTAILS IS COSTLY, BUT VERY EFFECTIVE TOOLS FOR THE PREVENTION OF FUNGICIDE RESISTANCE CALIXIN +

MANZATE and BENLATE / MANZATE

- USE OF COCKTAILS OF SYSTEMICS IS NOT RECOMMENDED
- COVERAGE IS IMPORTANT
- QUALITY OF FUNGICIDE MIXTURES
(TO ENSURE MAX. ABSORPTION OF FUNGICIDE)
- MANAGEMENT OF 'HOT SPOTS'
- BASIC FSM FOR MAJOR FUNGICIDE GROUPS

Strategies on Black Sigatoka control in Latin America (Del Monte Company).

The following strategies for Sigatoka management are formulated by Del Monte for the next two years:

1. application of Sigatoka fungicides will be done in accordance with FRAC recommendations at the country level;
2. mixtures of different molecules (contacts & systemics) will be used;
3. dependency on contact fungicides will remain;
4. improved IPM (drainage, fertilization, nematode control, etc.)
5. reduction of Sigatoka inoculum in the field through the sanitation;
6. improvement of fungicide application equipment (reduction of drift, better coverage, precise dose rates);
7. improvement of quality of mixtures (inclusion of fertilizers to the fungicide mixtures can tamper with the efficacy of fungicide, or damage the fruit);
8. use of resistance promoters such as Boost and Messenger
9. consideration of environmental factors (buffer zones, drift conditions, etc.)

SAFE USE OF PESTICIDES, RESIDUES AND ENVIRONMENTAL ISSUES RELATING TO SIGATOKA DISEASE CONTROL

Michael Ramsay

Introduction

It is important for all users of pesticides to be aware that all of these chemicals have the potential of being dangerous to the health of humans. This applies not only to those persons who apply the pesticides but also others who come in contact with them through spray drift or accumulation in soil, water or the food chain. There is also the situation of accidental or deliberate exposure to the concentrate in the container as a result of improper storage.

- ✓ The pesticides are also dangerous to non-target organisms that are a part of the ecosystem of the community where the spraying is being done. The pesticide is spread over a very wide area by water movement in runoff and through the food chain. Destruction of non-target organisms is not readily observed or studied, and the agricultural sector can do much damage without being aware of it.

Pesticide Dilution Effect

A false sense of security develops in the use of pesticides because of the dilution factor. In essence, the pesticide is diluted by various agents and it seems to disappear harmlessly into the environment.

These diluting agents are:

a) Air.

The spray droplets drift away in the air and the vast volume of air seems to completely absorb it.

b) Soil.

When the spray comes into contact with the soil it is absorbed and is not visible unless the chemical was very concentrated and/or had a marked colour. The large bulk of the soil seems to be able alleviate any potential problems.

c) Water.

Running water, either during rainfall or in streams and rivers, also seems to have a great capacity to wash away pesticides and dilute them to a harmless concentration.

In all of these instances, however, the pesticide is building up over time in the soil and standing water, including the underground water, which is the source of domestic water supplies in many areas. It is also moving up the food chain where it becomes more and more concentrated. Over time the original compound undergoes changes from chemical reactions with materials in the soil and water, and biochemical changes by bacteria and other organisms. Some of these products are more dangerous than the original pesticide.

d) Humans.

The human body seems to be able to absorb most pesticides over a prolonged period without any noticeable effect. The pesticides are diluted by body fluids, broken down bio chemically, and finally excreted. However, like the environment, the pesticides are building up unnoticed in the body, as are some of the products of the breakdown processes. When the physical symptoms finally occur after a long time, the link is often not made that pesticide contamination was the cause.

It is important to note that the risk of pesticide harm is in proportion to body weight. Therefore a child is much more at risk than an adult because of smaller size. This is the reason that children must be kept out of areas where there is the potential of pesticide contamination. As a practical example, during school holidays some mothers bring their young children to the banana fields, as it is inconvenient to leave them at home. However this practice should be discouraged especially when pesticides are being used.

Risk of Environmental Contamination From Sigatoka Spraying

Spraying against Black Sigatoka is done by aircraft or mist blower. Both of these result in much spray drift and environmental contamination due to the following:

- (a) The droplet size used is very small and this is prone to drift.
- (b) The mist blower sends the spray above the canopy up to twenty feet into the air, while the aircraft is even more problematic as it is releasing the spray from above the canopy. In both instances, the spray not only falls due to gravity but also can be blown by wind currents into non-spray areas. The aircraft is not able to confine the spray to only within the boundaries of the fields and some of the spray will inevitable end up in non-crop areas.

While there is much spray drift from Sigatoka spraying, the pesticides used are not very toxic and have been classified as only slightly hazardous. Therefore the danger to humans and the environment is not as great as might otherwise be expected.

Pesticide Labels

Important information

The labels supplied by the manufacturers of pesticides and attached to the pesticide container are the most available and useful source of information on the dangers of the particular pesticide and the procedures for its safe use. As a consequence, all persons involved in pesticide use, whether the manager or the mist blower operator, must take the time to know the information on the pesticide label and follow it.

Pictograms

Understanding a pesticide label requires that the reader can interpret the pictograms on it. These pictograms are simple line drawings depicting various information. They are used because many pesticide users are functionally illiterate but can be readily taught what the pictures are saying. An example of some pictograms and their meanings are shown in Figure 1 on the attached page.

Fungicide toxicity to humans

Figure 2 on the following attached page shows information on the labels of some fungicides used in Sigatoka control regarding their toxicity to humans. For example the labels tell us that eyes can be irritated by Tilt while they can be seriously damaged by Calixin. Benlate, Anvil and Calixin are all harmful if swallowed. In addition Anvil can cause burns. It can be concluded that although in general the fungicides are not particularly toxic to humans if used correctly, they have to be handled carefully.

Benlate example

Figure 3 shows a magnified copy of the information form a Benlate leaflet supplied by the manufacturer with the product. It includes information on possible irritation and allergic skin reaction to humans, and personal protective equipment that must be worn by persons who are at risk of exposure to the dilute and concentrated fungicide. It is interesting that the manufacturer does not include eye protection when working with either the dilute and concentrated fungicide or no respirator when using it diluted. The leaflet then gives recommendations on user safety. This type of information is common to all pesticide use and must be followed to avoid dangerous contamination of the user. Finally the leaflet gives information on environmental

information on environmental hazards. It is important to note that it is toxic to fish and therefore not recommended for application in fields where runoff can occur.

Tilt example

The information from a Tilt manufacturer's leaflet contains the following information about this fungicide with regard to the environment:

- Tilt 250 EC is toxic to aquatic organisms
- Do not contaminate water used for irrigation or domestic purposes, or water areas such as flowing or stagnant water by the disposal of product waste.
- The freshly treated area must not be grazed, nor food nor feed collected from it, all livestock is to be kept out.

Again this demonstrates that there can be risk of environmental harm from the fungicides used in Sigatoka control. Reading the labels, understanding the information, and following the recommendations are important for safe use of these pesticides.

PESTICIDE = PEST KILLER.

**How does the pesticide identify the pest that must be killed?
Only by the biochemical pathway, regardless of whether the organism is harmful or useful or human.**

SAFETY CONSIDERATIONS IN PESTICIDE USE

PURCHASE OF PESTICIDE

- container must be intact and free from chemical contaminating the outside
- container properly labelled with safety information
- seller must be able to provide correct information to the purchaser

TRANSPORT

- pesticide separated from humans, animals, food and feed
- damage to container and spillage prevented by the container being properly secured in the vehicle and carefully handled.

STORAGE

- securely lock away container outside of the house
- pesticide separated from humans, animals, food and feed
- properly labelled so that there is no confusion as to what it is and how it is to be used

Figure:1. Examples of Pictograms Used on Pesticide Labels

Figure:1. Pictograms

STORAGE Pictogram

Keep lockes away and out of each of children



ACTIVITY Pictograms



Handling liquid concentrate

Application by knapsack sprayer



Handling dry concentrate



ADVICE Pictograms

Wear gloves



Wear eye protection

Wash after use



Wear boots

Wear protection over nose and mouth

Wear respirator



WARNING Pictograms


Dangerous/harmful to animals





Dangerous/harmful to fish - do not contaminate lakes, rivers, ponds or streams



Figure 2.
Information on Labels of Selected Fungicides Used to Control Black Sigatoka

Benlate 50 WP Wettable powder (WP)		
Active ingredients benomy	g/kg 500	Company / undertaking Du Pont
Toxicity to man Harmful if swallowed Possible risks of irreversible effects	Countries where available Dominica Grenada Guadeloupe Martinique St. Kitts St. Vincent	

Tilt 250 EC Emulsifiable concentrate (EC)		
Active ingredients propiconazole	g/l 250	Company / undertaking Novartis
Toxicity to man Irritating to eyes	Countries where available Dominica Grenada Guadeloupe Martinique St. Lucia St. Vincent	

Anvil MS Oil miscible flowable concentrate (OF)		
Active ingredients hexaconazole	g/l 250	Company / undertaking Novartis
Toxicity to man Causes burns Harmful if swallowed	Countries where available Guadeloupe Martinique	


Calixin Emulsifiable concentrate (EC)		
Active ingredients tridemorph	g/l 750	Company / undertaking BASF
Toxicity to man Harmful if swallowed Irritating to skin Risk of serious damage to eyes	Countries where available Dominica Grenada St. Lucia St. Vincent	

Figure 3



Benlate®

fungicide

Wettable Powder

ACTIVE INGREDIENT	BY WEIGHT
Benomyl [Methyl 1-(butylcarbomyl)-2-benzimidazolecarbamate	50%
INERT INGREDIENTS	50%
EPA Reg. No. 352-354	TOTAL 100%

KEEP OUT OF REACH OF CHILDREN
CAUTION
PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS

CAUTION! MAY IRRITATE EYES, NOSE, THROAT AND SKIN

Avoid breathing dust or spray mist. Avoid contact with skin, eyes, and clothing. This product may cause a temporary allergic skin reaction in a few susceptible persons. This condition should be treated as an allergic dermatitis. There is no evidence of after effects or permanent injury.
 First Aid: In case of contact, flush skin or eyes with plenty of water for eyes, get medical attention.
 For medical emergencies involving this product, call toll free 1-800-441-3637.

PERSONAL PROTECTIVE EQUIPMENT

Handlers who may be exposed to the dilute through application or other tasks must wear:

- Long-sleeved shirt and long pants.
- Waterproof gloves.
- Chemical-resistant footwear plus socks.
- Chemical-resistant apron when cleaning equipment

Handlers who may be exposed to the concentrate through mixing, loading, application, or other tasks must wear:

- Long-sleeved shirt and long pants.
- Waterproof gloves.
- Chemical-resistant footwear plus socks.
- Chemical-resistant apron when mixing or loading.
- For exposures in enclosed areas, a respirator with either an organic vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C), or a canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G).
- For exposures outdoors, a dust/mist filtering respirator (MSHA/NIOSH approval number prefix TC-21C).

Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

ENGINEERING CONTROL STATEMENTS

Human flaggers must be in enclosed cabs.
 When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [40 CFR part 170.240 (d) (4-6)], the handler PPE requirements may be reduced or modified as specified in the WPS.

USER SAFETY RECOMMENDATIONS

User should: Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet. Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing. Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to fish. For terrestrial uses, do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark, except for the registered aquatic use on rice. Do not apply where runoff is likely to occur. Drift and runoff from treated areas may be hazardous to fish in adjacent areas. Do not contaminate water when disposing of equipment washwaters. Do not apply when weather conditions favor drift from areas treated.
 For registered aquatic uses: Aquatic organisms may be killed at recommended application rates

PHYSICAL OR CHEMICAL HAZARDS

Keep away from fire or sparks.

OPENING CONTAINER

- before opening the pesticide container, the spray equipment should be tested to determine whether it is working and that there are no leaks. If after mixing the chemicals the user discovers that the equipment is not working or is leaking, there is the risk that he will throw away the chemicals contaminating the environment if the equipment cannot be fixed within a day or two and no other is available.
- wear protective gear to avoid contact with skin and inhalation
- avoid spillage that would contaminate the person and/or environment
- avoid damaging container if all of the pesticide is not going to be used

MEASURE PESTICIDE

- the measuring container must be clean and must be of designed to pour without spillage
- great care needed to avoid spillage, contact with skin and inhalation
- accurate measurement needed to avoid excess pesticide application

MIX WITH OTHER COMPONENTS

- thorough mixing needed for uniform application at the correct dose rate

POUR INTO SPRAY EQUIPMENT

- spray equipment should have been checked before filling
- great care needed to avoid spillage, contact with skin and inhalation

SPRAY PLANTS WITH MIXTURE

- equipment must be calibrated to ensure application at the correct dose rate
- spray man must ensure uniform coverage to avoid some areas getting excess

STORE EXTRA PESTICIDE

- container must be intact and properly sealed, with no pesticide on the outside, and properly labelled

DISPOSAL OF EMPTY CONTAINER

- as much of the chemical as possible must be removed from the container prior to disposal. If the container is plastic or metal it must first be triple rinsed to remove the chemical and then punctured to ensure that it can no longer hold any liquid.
- ideally the container should be returned to the seller. However this facility is usually not available.

- the next best option would be to have it burnt in a very high temperature incinerator. However this is also usually not available. Burning in a regular fire at low temperatures can result in toxic fumes polluting the air and often much of the material still remains because of incomplete combustion.
- the best practical solution usually is to bury the container in an area that will not be disturbed, and is away from areas that must not be contaminated.

Centralized Management of Black Sigatoka for Export Banana Production The Jamaican Experience

Donald Elvey & Clifton Wilson

Centralized Management of Black Sigatoka for Export Banana Production

The Jamaican Experience

- What is centralized management?
- Need for centralized Sigatoka management
 - Black Sigatoka more aggressive than yellow Sigatoka
 - Timely application of the appropriate chemical

- To secure the long term efficacy of the systemic fungicides
 - *Proper chemical rotation*
 - *Correct dosage rate*
 - *Community spraying*
 - *Sensitivity testing*
- Ensure that the necessary input material are readily available
- To protect the export market - drawback encountered

Components of Central Management

- Training of Staff
- Disease forecasting
- Data Process

❖ COLLECTION OF BIOLOGICAL DATA

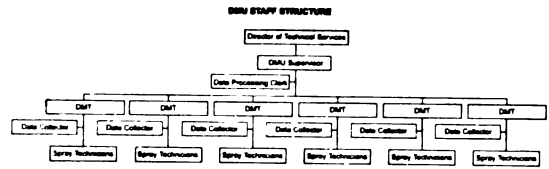


❖ Met Station



- Licensed (auxiliary) sprayers (LSM)
- Spray teams with distinct locations
- Sensitivity testing
- Planning meetings
- Disease Management Unit (DMU) staff structure

7



8

Project Operations

Types of services offered:

- Full service
- Partial service

9

Cost Components:

- Administrative Cost

Component

1. Labour: x1
2. Transportation: x2
3. Fuel mixture: x3
4. Supervision and mistblower maintenance: x4

11

- Material Cost

Component

Type of Chemical	Admin Cost	Emulsifying Agent & Oil	Chemical Cost	Total Cost Per Acre
TILT				
ANVIL				
CALXIN				
BENLATE				
TOPSIN				
BANKIT				
ZANCOZED				

12

Spraying Operations (2 sessions)

1st session

•Start 4:00 a.m. depending on the time of year



VEHICLE SHOWING EQUIPMENT AND CHEMICAL USED IN SIGATOKA MANAGEMENT



CORRECT POSITION OF SPRAY BOOM



CORRECT POSITION OF SPRAY BOOM



TREATMENT APPLICATION ABOVE PLANT CANOPY



SPRAY-MEN RETURNING FROM FIELD



END OF SPRAYING



•End at 9:00 - 10:00 a.m (drooping leave)



2nd session

- Each sprayman should spray approximately 30 acres per day. Important to reduce intransit time

Geographical Coverage OF DMU



Major Problems Encountered

1. Unpredictable Weather Patters - the weather pattern in the Rio Grande Valley is unpredictable, resulting in several spraying cycles being disrupted and cycles extended for up to one week at times.

2. Servicing of Fragmented and Small Banana Plots - apart from most farm holdings being small, e.g. one acre, they are also separated in fragments. This increases transit time and mixing which result in reduced spraying sessions and less acreage being sprayed.

3. **Farms not Prepared for Spraying on time - e.g not** sleeping. This is very frustrating and causes disruptions in the week's spraying programme, extended cycles, and wastes a lot of time that could be used to spray another farm.



4. **Poor Field Sanitation** - most fields have their particular problem, e.g. drainage and sanitation. This however contributes to slow recovery of fields with disease and hinders sprayers from moving effectively while spraying. N.B.: Deleafing is seldom done on farms - done mainly at pruning time.

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5. **Farmers Reluctant to use Calixin** - some farmers object to the use of Calixin on their farms due to so-called damage to fruits. This encourages the over use of Benlate/Topsin-M or Tilt.

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6. **Mechanical Breakdown of Mist-blowers** - this occurs frequently, resulting in time loss and reduced acreage covered per session. Blocking of the carburetor is mainly the problem due to lack of stability of the filter of the gas, therefore sediments go straight to carburetor and cause blockage.



7. **Steep Hill Sides** - most farms in the Upper Rio Grande Valley are on hill sides thus making it very difficult to move effectively when spraying, especially when the fields are wet and when coffee plants are inter-cropped with banana. Refilling of chemical is tedious.

8. **Flooding of River** - farms across the Rio Grande are often affected by floods. This results in extended cycles.

9. **Intransit Time Loss** - most farms are of small acreage thus spray time is reduced by moving from one farm to another for one spraying session.

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Achievements and Targets

Activity	Target	Achievement
Acreage Serviced	1300	1100
No. of service	140	123
YLS achieved	> 8	8.5
Chronshaw	<10	18
Maximum usage Triazoles	3 cycles	2
Maximum Usage Strobilurin	2	

25% of farms sprayed with Strobilurin

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CONTROLLING BLACK SIGATOKA DISEASE FOR DOMESTIC BANANA PRODUCTION: USE OF RESISTANT VARIETIES

Michael Ramsay

Introduction

Bananas and plantains grown for the domestic market are particularly at risk from black Sigatoka because the persons growing them generally do not have the knowledge or resources to control the disease. Also the plots are often too small for the owners to invest in spray equipment and be cost-effective, while a centralised spray programme will be inefficient and require much subsidy.

The alternative is to take out the black Sigatoka susceptible banana and plantain varieties currently being grown and replace them with new resistant varieties. While this seems the ideal and practical solution, there are a number of issues that have hindered its implementation. The main problem is that there is no perfect variety that will meet all of the requirements. As an example, a handout is attached giving the ideotype requirements for a new commercially acceptable banana hybrid. Much money and effort has been expended in several countries over many years to breed such a variety without success. Each variety developed that showed promise has always had one or more important characteristics missing.

Questions to Ask

Some varieties have been developed which are not perfect but may be good enough for a domestic banana and plantain programme. It is necessary to ask the right questions about these varieties and get specific answers in order to assess their suitability to a particular country or area.

The following are questions that need to be addressed. They are not in any particular order of importance. In fact all are important and if even just one is not satisfactory, the resistant variety may not be useful.

- **Resistance**
Is the variety really resistant to Black Sigatoka? Is it also resistant to other Musa diseases that may be in the country or which may enter the country at some time in the future?
- **Adaptability**
Will it show good growth and yield in the country's climate and soils?
- **Inputs**
Will it produce with minimal cultural and material inputs? This is particularly important for the domestic production sector, as these plots will generally get minimal care.
- **Acceptability**
Will consumers like the new variety with respect to the following?
 - appearance
 - taste
 - cooking characteristics (for example, the FHIA plantain varieties when ripe cannot be fried or boiled satisfactorily because they are too soft)
 - genetic modification, if this has been used to produce the variety.
- **Versatility**
Can the variety serve a dual purpose? (For example, some countries require a banana variety that can be eaten as a boiled green fruit or as a fresh ripe fruit. Similarly a plantain variety may be required that can be satisfactorily cooked either green or ripe. If the variety can only serve one function then the farmers may not want to grow it as it could limit their sales)
- **Risk**
Is there a risk of introducing a new pathogen with the variety (for example, Banana Streak Virus)?

Is there a risk that there will be an unacceptable level of mutants in the material that will be a problem for the farmers?
- **Cost**
How much will it cost farmers to change to the new variety? If the cost is significant compared to the farmer's financial resources and potential earnings, he will be unlikely to accept the new resistant variety.

Steps To Establish a Resistant Variety

The following sequence is needed in a country to successfully change over from varieties of banana and plantain susceptible to black Sigatoka to new ones that are resistant.

1. Identify potential varieties

This can be done by reading literature especially reports from breeding stations, corresponding with breeders at FHIA, IITA etc., and finally visiting the stations to see first-hand what may be suitable based on the questions discussed above.

2. Import plants

Enough material needs to be brought in at one time so that there is no prolonged delay in multiplying up sufficient plants to start testing. The material must be guaranteed free of pathogens to avoid importing a new problem.

3. Testing

There has to be rigorous testing of the varieties, comparing them against existing ones already being grown in the country. This has to involve replicated experiments that will produce data for full statistical analysis and must therefore have the input of a Biometrician from the planning stage to the final analysis. The researchers must be sure of their results, as a wrong choice of variety can be costly to the farmers and a loss of the researcher's reputation.

Testing has to be at three levels:

- a) **Agronomy.** This must be multi-site experiments in the country's various climatic and soil zones where farmers will eventually plant the variety. The trials should extend over at least three crops or three years, whichever is more.
- b) **Post-harvest.** This will include shelf life and ripening studies.
- c) **Taste-testing.** This must use a panel of persons in a controlled environment, with the samples being tasted only identified as numbers. The taste testing must be a comparison between the new variety with the ones already being used in the country (rather than just the new variety) and samples must be prepared in the same way that consumers are accustomed to.

4. Multiplication

When a variety has been selected, it must be multiplied or ordered from abroad so that there is sufficient to meet the demands of farmers. Accurate estimates of demand and scheduling are critical to avoid having too many plants when farmers don't need them and then an inadequate number during the planting season.

5. Replant

The removal of the old varieties susceptible to black Sigatoka and replanting with the new resistant one requires a well-planned programme. Funding must be put in place and the extension staff will have much farmer education to do.

Conclusion

The use of resistant varieties for the domestic banana and plantain production sector is ideal but involves many considerations. Careful and rigorous testing must be done and it may turn out that at this time there is no suitable variety for the country's needs.

IDEOTYPE REQUIREMENTS FOR A NEW COMMERCIALY ACCEPTABLE BANANA HYBRID

Resistance Requirements

1. Resistance to all known races of Fusarium wilt (races 1-4)
2. Resistance to Sigatoka diseases
3. Tolerance to *R. similis* and other nematodes

Agronomic Requirements

1. Yield equal to present 'Cavendish' cultivars
2. Dwarfism similar to 'Grand Nain'
3. Ratoon at the same rate as 'Grand Nain' or exhibit a shorter ratoon cycle
4. Exhibit regulated sucker development

Quality Requirements

1. Long fingers with acceptable curvature and having pedicel and finger strength equal to the present 'Cavendish' cultivars
2. Flavour acceptable compared with 'Cavendish' cultivars
3. Fruit with similar ripening period and tolerance to physical stress as 'Cavendish' cultivars

Quoted from "Banana and Plantain Breeding" by R. Ortiz, R.S.B. Ferris & D.R. Vuylsteke, Ch.5 P.113 in "Bananas and Plantains" S. Gowen ed. Chapman & Hall publishers, London, 1995.

Practical Example of Analysis of Pesticide Contamination Risk on a Farm

Figure 4 shows a farm with banana and plantain, which will be sprayed. The farm should be evaluated along the following lines:

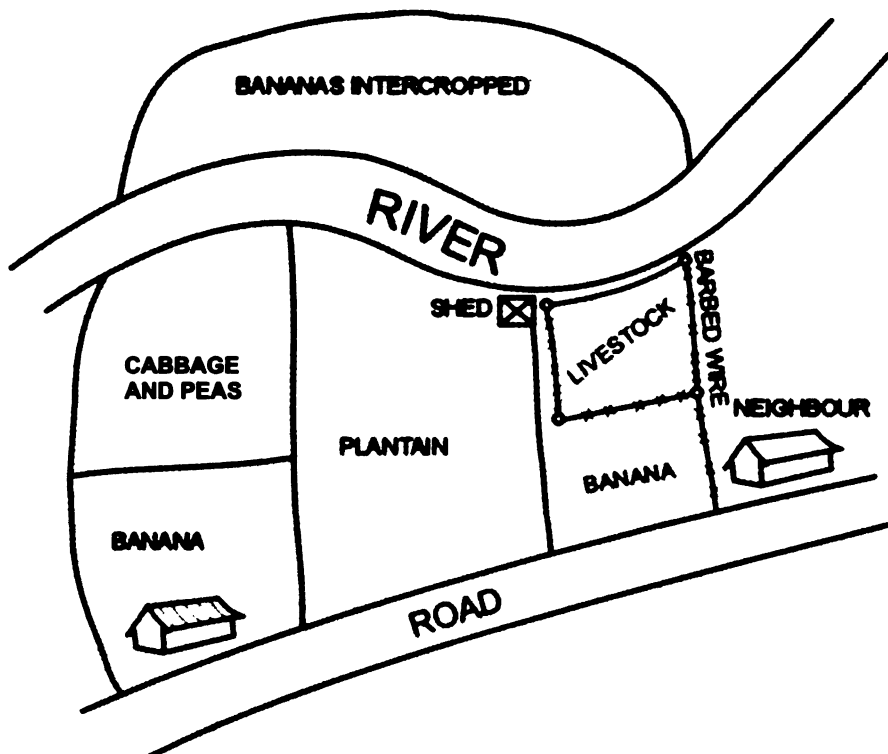
1. Where is the farmer most likely to store the spray chemical?
2. Where is he most likely to mix the chemicals prior to spraying?
3. What areas are at risk of contamination?
4. What can be done to reduce the risk of contamination?

Possible answers:

1. Storage will most likely be in the house as this is the most secure and convenient. However this will present a risk of contaminating the occupants. The storage area should at least be in a locked area on the outside of the house. It would have been better in the shed except that the structure is near the livestock and there is a danger from flooding of the river.
2. The farmer is most likely to mix the spray chemicals close to where he stores them. It would be best to mix them in the field where spillage would not pose a hazard to humans and livestock.
3. Areas at risk from pesticide contamination include the following which are not in any particular order:
 - Farmer's house; from storage, mixing and spray drift
 - Neighbour's house; from spray drift
 - Livestock; spray drift onto animals, animal feed and drinking water
 - River; from spray drift, runoff, and possible spillage when crossing to spray

- Road users; from spray drift
 - Other crops; spray drift onto intercrops and the cabbage and peas
 - Bananas and plantains; spray drift from the pesticides sprayed on the other crops
4. To reduce the risk of pesticide contamination from the spraying of the bananas and plantains against Sigatoka, plants should be removed from very close to the houses, river, livestock and road. Green barriers could be planted. Spraying should be done when there is no wind to minimize drift. Finally the pattern of which crop is planted in what location could be changed so that the crop requiring the least spraying should be near to the houses, livestock, river and road.

Figure 4. Practical Exercise to Assess Areas at Risk of Pesticide Contamination on a Farm with Bananas and Plantains being Sprayed against Black Sigatoka



Management of Black Sigatoka on Susceptible Varieties for Domestic Banana Production

Donald Elvey

<p>Management of Black Sigatoka on Susceptible Varieties for Domestic Banana Production</p> <p>1</p>	<p>Introduction</p> <p>In Jamaica, black Sigatoka has destroyed over 70% of the acreage grown for local banana consumption in some parishes. The exception is in the western parishes where disease management is an integral part of banana production, both for export and local market. It is important to note that even the tetraploid series that was expected to show tolerance to black Sigatoka have succumbed.</p> <p>2</p>
<p>Background</p> <p>Market Demand</p> <p>Change in Demand</p> <ul style="list-style-type: none">• Agro processing• Chips• Food drink• Ripening market <p>3</p>	<p>Impact on Prices</p> <p>Consequences</p> <ul style="list-style-type: none">• Praedial larceny (30%)• Importation of bananas• Impact on farmers attitude to the• local trade <p>4</p>

<p>Reasons for Rapid and Extensive Decline of Domestic Banana and Plantain Production in Jamaica</p> <ul style="list-style-type: none"> • Late detection of disease • Farmer unaware of the presence and impact of black Sigatoka • Lack of disease management programme, except for western Jamaica • Poor plant nutrition • Need for nematode and borer control • Water management • Population control • Inability of growers to procure inputs and equipment • Inability of growers to procure input and equipment • Increase price of inputs <p style="text-align: right;">5</p>	<p>Management Strategies - with black Sigatoka, banana and plantain production is not a fixed deposit investment</p> <p>Objective: To preserve the present crop and successive generations</p> <p style="text-align: right;">6</p>
<ul style="list-style-type: none"> • Education Programme <ul style="list-style-type: none"> - extension methodology - Sensitize farmers, officers and general public - Technical training programs - Provision of hand books, pamphlets, flyers, etc. • Spray Programme <ul style="list-style-type: none"> • Spray at the onset of the rainy season • Apply treatment 16-18 days during the rainy season • During the low pressure season spray at 28 days interval • Use 2 cycles of Triazoles per acre per year • Total of 13-14 cycles per year • Chemical management <p style="text-align: right;">7</p>	<ul style="list-style-type: none"> • Use of More Tolerant Varieties <ul style="list-style-type: none"> • Remove the more dwarf cavendish cultivars <ul style="list-style-type: none"> - Gran nain - William hybrid • Robusta • Tetraploid • Plant Nutrition <p>Fertilize at least twice per year using 8 bags per acre. Zinc application must be an integral part of the fertilizer programme.</p> <p style="text-align: right;">8</p>
<ul style="list-style-type: none"> • Apply Nematicide <p>One bag per acre per year</p> • Population Control • Field sanitation <p>leaf pruning</p> • Drainage Control <p><i>Pay attention to:</i></p> <ul style="list-style-type: none"> - perimeter drain - main drain - clean before rainy season <p style="text-align: right;">9</p>	

RISK ASSESSMENT FOR THE IMPACT OF BLACK SIGATOKA DISEASE

Michael Ramsay

Introduction

The outbreak of Sigatoka disease does not only depend on environmental factors but on the availability of input material and management skills.

Components and Considerations

- **Contact and trading with *red light* countries**

- Central & South America
- Cuba
- Dominican Republic
- Jamaica
- Bahamas?

- **Quarantine measures at the necessary ports of entry**

- Rainfall occurrence
- Drainage control
- Equipment availability
- Availability of chemicals
- Variety- cultivars
- Spray cycles
- Sensitivity status

- **Preparedness and institutional strengthening**

PRACTICAL SESSION

Introduction

In carrying out a risk assessment for the risk of entry, the following must be considered:

1. Pathogen must be present
2. Host must be in the area to come in contact with the pathogen

IICA Questionnaire

A questionnaire was done by IICA for eleven Caribbean countries on the possibilities of entry of black Sigatoka. Some questions on the questionnaire are summarised and tabulated below.

IICA QUESTIONNAIRE OF ELEVEN COUNTRIES NOT YET INFECTED WITH BLACK SIGATOKA

<i>Ships/airlines from infected countries</i>	54%
Agricultural produce from infected countries	36%
No customs forms with plant quarantine questions	36%
No carrier inspections at entry ports	36%
Express mail from infected countries	73%
Accept offloading of international garbage	73%

All of the questions relate to possible sources of entry of the black Sigatoka pathogen and the more that are applicable to a particular country is the greater the risk. Each country therefore has to do its own assessment and to devise plans for closing these gaps as much as practical.

Matrix Analysis

Another method of analysis of the risk of entry of the black Sigatoka pathogen to a particular country is matrix analysis using the two factors sources of the pathogen entry and the amount of movement from infected countries. The more of either is the higher the risk. This is reflected in the numerical value assigned to the particular situation in the country.

PATHOGEN		SOURCES		
		Few	Some	Many
MOVEMENT	Little	1	2	3
	Some	2	3	4
	Much	3	4	5

In the practical session a hypothetical island shown in Figure 1 on the following page will be assessed. Any resemblance to a real country is purely coincidental.

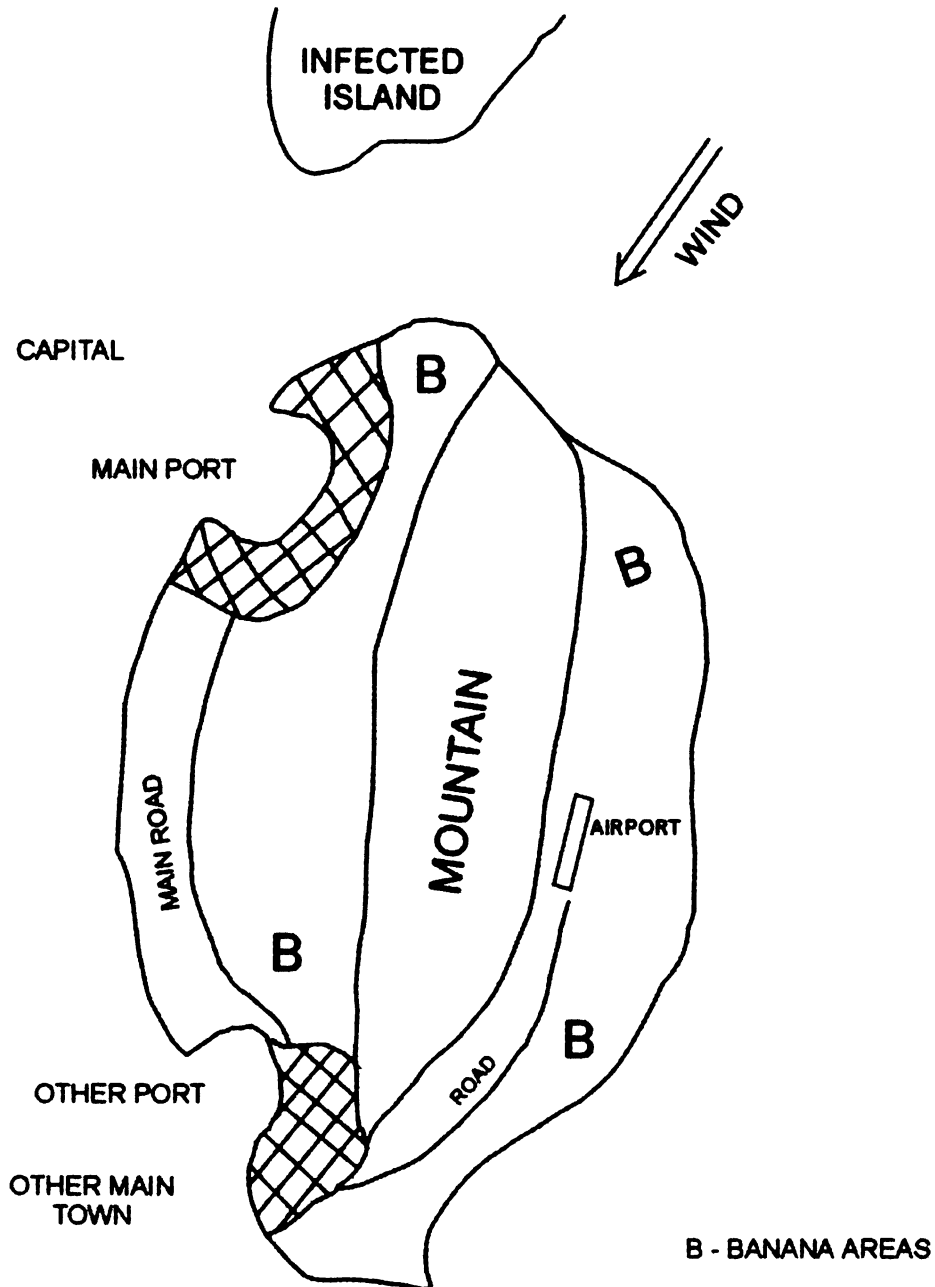
Workshop Discussion

The points to note are:

- a) The most likely points of entry would be the seaports and due to the movement of people and goods, and the northern tip of the island due to the wind direction from the infected island.
- b) After entry there are several aids to spread including the wind and movement of infected material along the roads by farmers and gardeners.
- c) Barriers to the spread will include the mountain and urban areas because of less density of the hosts. However the problem in urban areas it is less likely that any control measures will be used when black Sigatoka becomes established.

PRESENTATIONS BY SELECTED PARTICIPANTS ON THE RISK ASSESSMENT OF THEIR COUNTRIES BASED ON THE CHECKLIST DEVELOPED BY CLIFTON WILSON

Figure1. ASSESSMENT OF RISK OF BLACK SIGATOKA ENTRY FROM VARIOUS SOURCES



Development of a National Programme for Black Sigatoka Management

Janet Conie

Introduction

The production of bananas for carbohydrate dietary source, exportation and wage-provision has been of major significance to the Caribbean and specifically Jamaica since the 1950s. Currently, it is surpassed only by sugar cane in exports and the number of citizens employed by any agricultural industry in most countries. The exception to this is the Windward Islands, where banana production is the primary industry and employ up to 60% of the population. The yearlong production generates cash flow and employs approximately 20,000 employees directly, mainly located in the rural areas.

A national plan for Black Sigatoka management must be devised, accepted, and initiated before the disease is discovered in new territories. Quarantine measures to prevent entry of the disease and training of technical personnel must be on going. A systematic plan must identify, garner and implement (where nectar) the following:

- All the possible effects, risks and consequences of the disease;
- all the necessary disease identification skills, management technology, procedures and training;
- the constraints to achieving a successful programme; and
- resources and associated costs needed to economically carry out effective management.

After the outbreak and identification, appropriate strategies for survey, containment and management must be catapulted into action. When eradication exercises are not implemented and there are lengthy delays in implementation of management programmes results can be catastrophic. In all territories (except Australia) that have been affected by Black Sigatoka to date, it took two years for the disease to completely displace Yellow Sigatoka. This is particularly serious for the plantain crop, which is not affected by Yellow Sigatoka, as usually there are no pre-existing disease control measures. In Jamaica the plantain field where the disease was discovered, disappeared completely in a few years.

Effects of Black Sigatoka in the Caribbean

- Reduces yield and quality of banana and plantain.
- Reduces individual farm family and foreign incomes, as well gross national product of exporting countries.
- Threatens the availability food of domestic carbohydrate food source and livelihood of rural population.
- Diversion of exports fruit and chemical inputs for disease control from export industry to the local market.
- Increased migration of people from rural to urban areas and poverty.

Possible Components of National Sigatoka Management Programme

Options for Domestic Production

1. Replacement of susceptible cultivars with resistant banana and plantain varieties.
2. Diversification from banana to other crops or cottage industries.
3. Supply local market from export production in exporting countries or importation into countries with no export banana/plantain industry.
4. Governmental or external support to provide management system to control the disease for domestic farmers.

Constraints to the Implementation of Programmes for Domestic Production:

1. Replacement with resistant varieties:
 - a. Unavailable locally. Plantlets must imported in tissue culture, grown out, screened and multiplied in the field. This due to the induction of BSV in the tetraploid varieties when they are multiplied by tissue culture.
 - b. Screening and multiplication process is slow and it takes 1-2 years before distribution can be started.
 - c. Nursery technology may not be available locally and training of nursery managers and technicians or is required.
 - d. High capital costs.
2. Diversification from banana to other crop:
 - a. Identification of crop, which can be cultivated on banana lands and that can generate similar cash flow, minimum crop care and identified market.
3. Supply local market from export production in exporting countries or importation into countries with no export banana/plantain industry:
 - a. Domestic farmers lose livelihood.
 - b. Possible increased price of local bananas and plantain.

- c. Reduction in export production.
- 4. Governmental or external support to provide management system to control the disease for domestic farmers.
 - a. High recurrent cost makes it unsustainable.

Options for Export Production

Implement an appropriate chemical and cultural (integrated) disease control programme consisting of:

1. An integrated disease control programme with climatic and biological disease data analyses.
2. Fungicide sensitivity monitoring programme.
3. Guaranteed supply of chemical inputs with all fungicides, oil and emulsifier for disease resistance strategy.
4. Technically competent centrally managed disease management unit.
5. Research support to process new developments in science and technology for disease control and carry out applied research.
6. Extension or technology-transfer support to assist farmers to improve cultural practices and implement new directives in disease management after verification by research.

Constraints to the Implementation of Integrated Disease Control Programme:

- a. medium to low levels of technology, crop nutrition and educational background on many small farms
- b. uneven topography (cultivations on hillsides and deep closed valleys).
- c. non-contiguous banana acreages and the proliferation of abandoned cultivations.
- d. High level of technology required and associated capital and recurrent costs.

A summary of the national Black Sigatoka management programme was given in the first paper presented in the technical session of this workshop "Over-view of Black Sigatoka Management in Jamaica". It can be used as guide to develop programmes for individual countries. However, modifications must be made according to the individual need and constraints.

Recommendations

All of the options proposed are recommended for implementation providing the requisite costs and resources can be obtained. The objectives of securing the local food source, sustaining the export production and protecting the environment will be realized. However, in terms of long-term cost effectiveness and sustainability, the domestic banana and plantain production is best secured by replacing the current cultivars with resistant varieties. On the other hand, the export industry has no options. Long-term economical costs and sustainability can only be guaranteed by the implementation of all the options identified. An integrated disease management strategy monitored by fungicide sensitivity testing and supported by applied research and technology transfer systems.

APPENDICIES

APPENDIX I: Agenda Opening Session, Technical and Practical Sessions

AGENDA OPENING SESSION

Tuesday, October 2nd

AGENDA

08:30-09:15 OPENING SESSION

Welcome and Introductions

Chair: Mr. Aaron Parke: Permanent Secretary Ministry of Agriculture

Opening Remarks

Dr. H. Arlington Chesney - Director, Caribbean Regional Centre, IICA
Representative in Trinidad and Tobago & Representative a.i in Jamaica

Greeting

Mr. Sebastian Coppieters Technical Assistant, Banana Export
Company/European Union Support Programme (BECO-EUBSP)

Keynote Address

Hon. Roger Clarke, Minister of Agriculture

Vote of Thanks

Mr. Byron Noble, Agricultural Trade Specialist, IICA Jamaica

Closing Remarks

Chair: Mr. Aaron Parke

AGENDA - Technical Meeting

Tuesday, October 2nd

AGENDA

- 08:00 **Registration**
- 08:30 **Opening Ceremony**
- 09:15 **COFFEE BREAK**
- 09:30-12:00 **Moderator - Mr. Everton Ambrose**
- Overview of black Sigatoka in Jamaica and the Caribbean **Janet Conie****
- Introduction and spread of black Sigatoka in climatic zones in Jamaica and impact on agricultural communities **Clifton Wilson****
- Life cycle of *Mycosphaerella fijiensis* and epidemiology of black and yellow Sigatoka diseases **Marina Young****
- 12:00 **LUNCH**
- 13:30-16:00 **Methods of prevention and containment of black Sigatoka to new territories **Clifton Wilson****
- The effects and differences of black and yellow Sigatoka disease on banana **Janet Conie****
- Methods of surveying to identify outbreak and spread of black Sigatoka disease - **Phillip Chung****

Wednesday, October 3rd

AGENDA

08:00 Departure to St. Mary Banana Estates (Recognizing the difference between black and yellow Sigatoka (Practical Session))

COFFEE BREAK

Black Sigatoka management for export banana production

Methods of disease assessment for efficient control in Jamaica of black Sigatoka disease - **Janet Conie**

Climatic data collection for predicting disease outbreak and efficient scheduling of applications - **Marina Young**

Manipulation of biological and climatic data to make the best decisions on fungicide strategy and schedule; advantages and disadvantages - **Janet Conie**

Hot spot management - **Marina Young**

LUNCH

Collection of disease data in the field (Practical Session) - **Janet Conie, Marina Young, Michael Ramsay, Leslie Rodney, Albert Watts**

Mixing, application and coverage check of fungicides on small farms
Clifton Wilson

Safety measures in pesticide handling **Donald Elvey / Winston Tackore**

Thursday, October 4th

AGENDA

08:30-10:30 Moderator - **Mr. Michael Ramsay**

Fungicide strategies for efficient, economical control and resistance management – **Janet Conie**

The variability of Sigatoka pathogens and climatic conditions in different territories and the necessity for appropriate control strategies and research (local and international research update) – **Marina Young**

Central management as a tool to prevent fungicide resistance – **Clifton Wilson**

10:30-11:00 **COFFEE BREAK**

11:00-12:00 Introduction to fungicide sensitivity monitoring for the prevention or delay of fungicide resistance – **Janet Conie / Marina Young**

12:00-13:30 **LUNCH**

13:30-16:30 Banana Industry Research Department Laboratory (**Practical Session**)
Fungicide sensitivity monitoring procedures **Marina Young**

Friday, October 5th

AGENDA

08:30-10:30 Moderator - **Mr. Sebastian Coppieters**

Safe use of pesticides, residues and environmental issues relating to Sigatoka disease control – **Michael Ramsay**

Central management of black Sigatoka for export production: The Jamaican Experience – **Clifton Wilson / Donald Elvey**

Controlling Black Sigatoka Disease for Domestic Banana Production:

Management of susceptible varieties for domestic banana production – **Donald Elvey**

Use of resistant varieties – Michael Ramsay

10:30-11:00 **COFFEE BREAK**

Carrying Out Risk Assessments for the Impact of Black Sigatoka Disease:

11:00-12:00 Components and considerations – **Clifton Wilson**

12:00-13:30 **LUNCH**

13:30-15:00 Development of a national programme for black Sigatoka control – **Janet Conie / Michael Ramsay**

Discussions and evaluation of workshop

15:00 **CLOSING REMARKS – Everton Ambrose**

APPENDIX II: LIST OF PARTICIPANTS - CARIBBEAN SIGATOKA WORKSHOP, JUNE 2nd 5th, 2001

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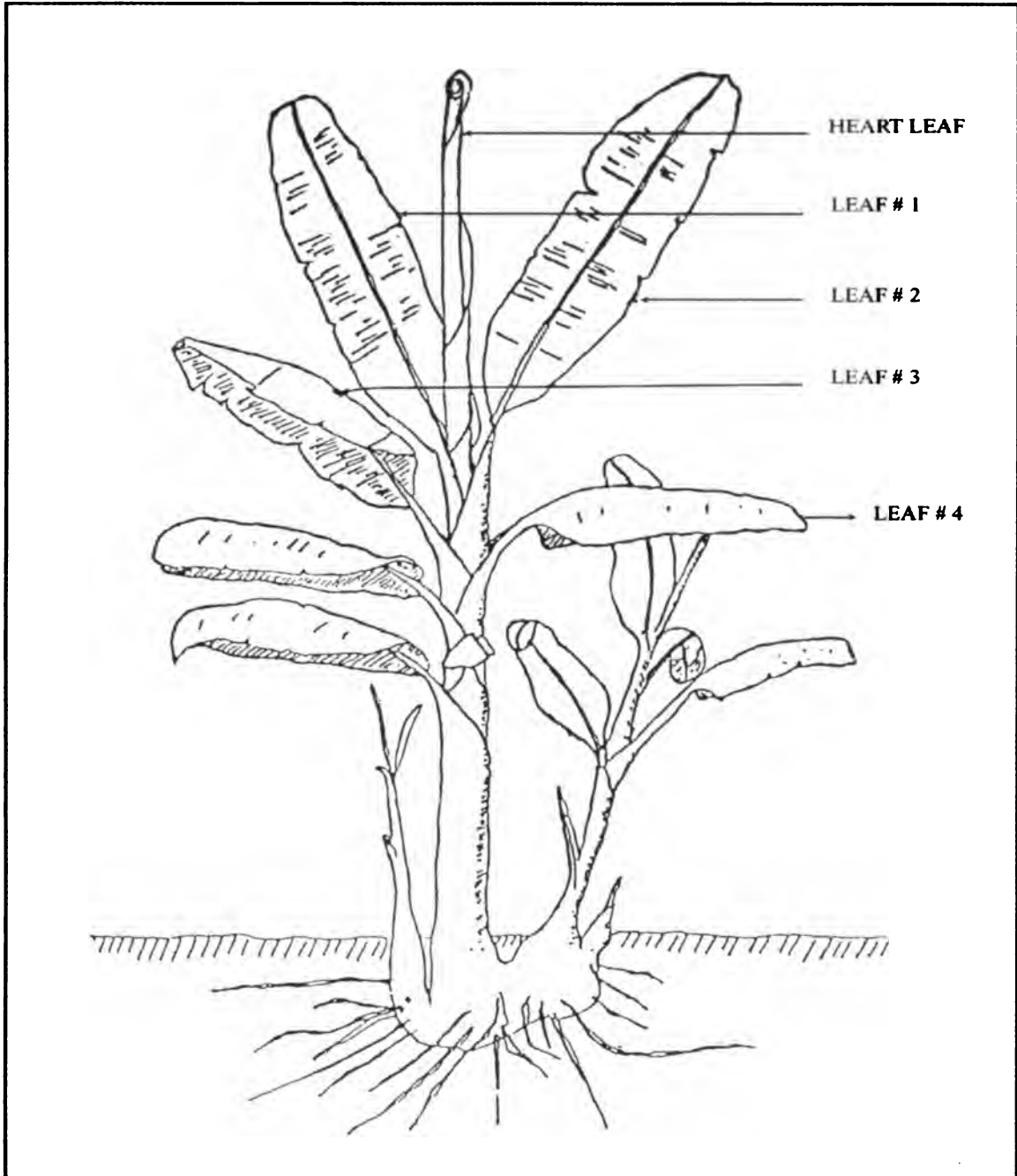
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APPENDIX III PLANT LEAF RELATIONS



Plant Leaf Relations

ANNEXES

New Disease Threats to Banana Cultivation in Latin America.

Selection of *Musa* species were geared towards seedless fruits. Evolution of edibility in the *Eumusa* cultivars most probably began with wild *M. acuminata* subspecies, which occur naturally in the area stretching from South Asia to Australia. Another key element was believed to have been hybridization with *M. balbisiana*, a more drought-tolerant species (this integration enabled banana to be grown in areas where rainfall is seasonal) Malaysia was considered as the center of banana species. However the latest research findings support theory that Philippines and New Guinea are the center of origin of *Musa* spp. **Knowledge of banana origin is important for the understanding possible disease threats to the species of banana cultivated commercially.**

The following diseases can pose threats to the commercial banana in Latin America and Caribbean in the future:

1. Septoria Leaf Spot (*Septoria musae*)

For the first time reported in India in 1992 on *Mysore*. It is appears to be the dominant leaf spot in Thailand, West Malaysia, Sri Lanka and southern India. Symptoms of disease are very similar to Sigatoka. Young leaves are not affected.

The fungus has Septoria as an imperfect stage and *Mycosphaerella* as a perfect stage (Annon., 1995). Phylogenetic analysis based on sequences of the ITS of ribosomal DNA from the *Mycosphaerella* sp. causing Septoria leaf spot, *M. musicola*, *M. fijiensis*, *M. musae* and *P. musae* has confirmed that all are different species.

Disease cycle & epidemiology:

No research has yet been undertaken on this disease

Control:

Septoria leaf spot may be controlled by the same chemicals that control Sigatoka disease.

2. Freckle caused by *Guingardia musae*. Freckle is a leaf- and fruit spotting disease. Common in South and East Asia and Australia Oceania, Africa

(Congo, Zambia) & the Caribbean (D. Republic, Jamaica and St. Lucia)-needs verification].

FRECKLE IS REGARDED AS MORE SERIOUS THAN BLACK LEAF STREAK ON 'PEI-CHIAO' AAA CAVENDISH SUBGROUP) IN TAIWAN AND ITS EMERGING AS A SIGNIFICANT DISEASE ON PLANTATIONS OF "GRAND NAIN" (AAA CAVENDISH SUBGROUP) IN THE PHILLIPINES

Disease affects leaves and fruits (flecking on the fruit is very severe making the unmarketable). Disease is difficult to control. Sanitation (removal of lower, diseased leaves) and bagging bunches to help prevent fruit infection are practiced. Mancozeb show efficacy in controlling disease. Mineral oil is ineffective. Propiconazole now is preferred fungicide.

3. **Fusarium wilt, known locally as Panama Disease**

- race 1 affects 'Lady Finger', 'Sugar' banana & Gross Michel;
- race 2 affects Blugoe;
- race 4 affects Cavendish group;

4. **Blood disease caused by fungus *Ralstonia solanacearum*.**

Disease occurs mostly in Pacific on desert and cooking banana, and causes wilt and total death of plant. Symptoms are similar to Moko disease

5. **Black rust disease caused by *Uromyces musae*.**

Disease described in Australasia Oceania, Asia (Malaysia & Phillipines) and Africa (Congo, Nigeria)

Cavendish cultivars are susceptible to rust when oil-sprayed (Firman, 1972)

Disease causes development of linear lesions, mainly on the lower surface of older leaves. Presence of uredosori provides entrance for the secondary pathogens (*Cordana musae*)

6. **Virus diseases:**

- **Bunchy Top virus**
- **Bract mosaic**

Both viruses transmitted by insect vectors and with infected plant material. Eradication is not effective. Prevention of virus introduction is the most important.

Movement of plant material should be only through the tissue culture from the certified sources.

Update on New Technologies for the Control of Black Sigatoka

- **Update on genetic transformation searching for Black Sigatoka resistance, (George Sandoval, CATIE, Costa Rica)**

According to the data from United Nation, approximately 29 000 000 hectares are presently cultivated worldwide with use of transgenic plants.

Development of transgenic banana plants with desired characteristics is possible through the biotechnology. Presently, work is in the progress for the development of such banana at CATIE, Guapiles, and Costa Rica. At the moment, chemical compounds responsible for the balancing of Sigatoka pathogen within the plant were identified and introduced into the plant genome.

- **Messenger a new technology for plant protection**

Development of new product MESSENGER is new technology available for disease control, including the Sigatoka disease on banana.

Messenger, is a biological product introduced to the USA market in 2001. It is approved for use on range of organically grown crops. Messenger active ingredient is HARPIN PROTEIN, isolated from bacteria *Erwinia amylovora* or *E. syringae*.

Harpin Protein does not go into the plant, but trigger mechanism of metabolic resistance by promoting certain proteins within the plant (usually within 48 hours). Resistance mechanism is a broad spectrum. Messenger is widely used on a broad spectrum of crops including cereals, vegetables, fruits (pineapple, mango, coffee), seed treatment, post-harvest application (citrus). Use of messenger drastically reduced number of fungicide applications (for instance, use of Messenger on strawberries reduces total use of fungicide by 70%). Use of the product on banana is in the experimental stage. Messenger is presently being tested on banana in Honduras and Ecuador. The protocol for MESSENGER's use on banana is to be developed.

Product has 3% of active ingredient, manufactured in the granular form, and applied as foliar spray at the dose rate of 2-6 oz./acre.

Product was marketed by the manufacturer in year 2001.

- **Effect of Boost® on the resistance mechanism of banana against parasitic nematodes, by Syngenta, Costa Rica. (Transparency with both trials data)**

Boost® was introduced to the market as a plant immune system activator in controlling Black Sigatoka just few years ago. Further research by Zeneca Company on the effect of plant activator Boost (*acybenzolar-s-methyl*) on banana showed that regular application of product stimulates defence mechanism of plants against *Rodopholus similis*, the major banana nematode. It was demonstrated with the pictures, that after repeated exposure of plants to Boost, there is re-arrangement in the root cells, which makes nematode penetration more difficult.

- **Update on the fungicide efficacy trials carried out in Jamaica for control of Black Sigatoka (1998 – 2001)**

1998-1999 Efficacy of the following fungicides was evaluated:
fenpropimorph (VOLLEY® 88 OL) – new morpholine (BASF)
epoxiconazole (OPAL ®7.8EC) – new triazoles (BASF)
hexaconazole (ANVIL® 25 SC) – triazoles (ZENECA)
azoxystrobin (BANKIT ®25 SC) – new strobilurin (ZENEKA)

Efficacy of spray oil BANOLE® (Total Company, France) was compared with SPRAYTEX® (Texaco, USA) by evaluating Sigatoka disease intensity.

1999- 2000 Efficacy of the following fungicides was evaluated:

difenoconazole (SICO 250EC) triazoles (BAYER)
tebuconazole (FOLICUR 3.6 F) triazoles (BAYER)
bitertanol (BAYCOR 30 DC) triazole (BAYER)
trifloxystrobin (TEGA 75% EC) new strobilurin (BAYER)
acybenzolar-s-methyl (BOOST 500 SC) plant activator (ZENEKA)

2000-2001 Evaluation of effectiveness of plant stimulator BOOST in controlling black Sigatoka and plant parasitic nematodes were evaluated.

STAGES OF BLACK SIGATOKA



STAGE 1:
Small speck visible on the under surface of the leaf



STAGE 2:
Small brown speck lengthens and becomes a visible yellow streak on the upper surface of the leaf



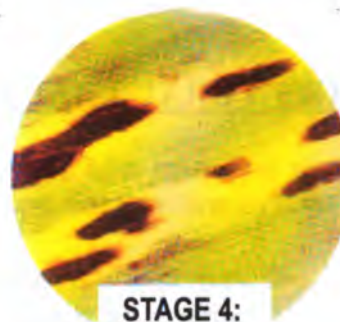
STAGE 3:
Dark streak lengthen and widen with no definite border. Black Sigatoka sporulates at stage 3.

DISEASE SYMPTOMS



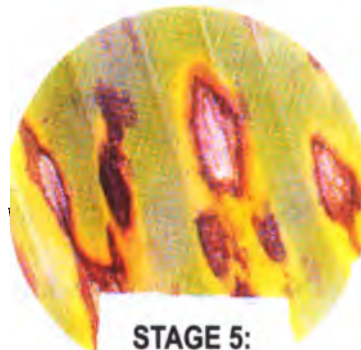
STAGE 3:

STAGE 4:
Streak becomes a dark brown or black spot and develops border. May have a yellow halo.



STAGE 4:

STAGE 5:
Centre of the spot turn to grey colour and dry out, surrounded by dark brown or black ring and yellow halo.



STAGE 5:

Factors Affecting Leafspot Development

FIELD HUSBANDRY

Field conditions that encourage a moist and warm environment will contribute to the development of Sigatoka. The following conditions may increase the relative humidity and temperature in field and hence predispose the plants to a greater chance of Sigatoka outbreak:

- *Overcrowded fields*
- *Poor weed control*
- *Improper drainage*
- *Insufficient pruning of infected leaves*

SIGATOKA CONTROL

The correct approach in controlling Sigatoka is to decrease the level of inoculum in the field and to reduce or eliminate the conditions that encourage the build up of Sigatoka disease. It does not depend solely on the timely and strategic use of appropriate chemicals, but, equally, on strict cultural practices.

CULTURAL PRACTICES

It is important that the recommended cultural practices for banana be implemented to achieve and maintain acceptable Leaf Spot control. These include:

- ❖ *regular de-trashing or de-leaving to remove dead and infected portions of leaves as these would contribute to re-infection and high levels of spore inoculum.*
- ❖ *preventing overcrowding of fields by:*
 - *planting at the correct spacing*
 - *pruning mats at regular intervals*
- ❖ *adequate drainage systems.*
- ❖ *good weed management*
- ❖ *good nematode and borer control*

- ❖ *adequate fertilization*
- ❖ *ensuring that fields are ready for spraying by sleeving bunches on time (non sleeved bunches will suffer chemical damage if sprayed)*

Within this framework, chemical treatments should provide effective and economical Sigatoka control and cause no unnecessary damage to the environment.

Disease Management Supervisors should be aware that many farmers underestimate the impact of poor field conditions on the development of Sigatoka and, often, rely only on chemical treatments. It is the duty of Disease Management Supervisors to sensitize the farmers to this issue.

**Methods of Biological Disease Assessment
and Climatic Data Collection for
Black Sigatoka Control**

Janet Conie

BANANA EXPORT COMPANY (JAMAICA)
RESEARCH DEPARTMENT

CRONSHAW DATA

Farm: _____

Date: _____

Section: _____

Collector: _____

Plant Number	Sigatoka Stages on Leaves					Remarks
	1	2	3	4	5	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Plant Number	Stages Multiplied by Factors					Total
	5	4	3	2	1	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Average Cronshaw Value						

STAGES	DESCRIPTION
1	Small yellow flecks
2	Streaks up to 2 mm brown in colour
3	Brown streaks broadening and lengthening
4	Spots (oval or round) with definite border
5	Centre of spot grey and thin in texture

BANANA EXPORT COMPANY (JAMAICA)
RESEARCH DEPARTMENT

YLS DATA

Farm: _____

Date: _____

Section: _____

Collector: _____

Plant Number	YLS	Number of Functional Leaves	Remarks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
TOTAL			
AVERAGE (Total ÷ 25)			
% Of plants with infection on leaf 7 or younger. Count all plants with YLS ≤ 7 and multiply the total by 4 or (100/25)			

Meteorological Data Collection Form

Location: _____

Data collector: _____

Month /Date	Temperature °C		Rainfall (mm)	Evaporation		Remarks
	Minimum	Maximum		Tube reading	Actual*	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
TOTAL:						

*Weekly evaporation calculated as total for the week.

Manipulation of Biological Disease and Climatic Data to Determine Spray Schedule for Black Sigatoka Control

Janet Conie

SIGATOKA DISEASE INTEGRATED MANAGEMENT SYSTEM

Calculation Exercise

Station: _____

Year: _____

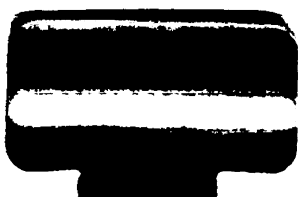
Week No.	YLS Avg.	Cronshaw Value	R	E	E _w	A	D	S D T	LWS	NWS	F	Re- marks
1	10.5	9.0	91	28.0							Tilt	
2	10.1	8.2	19	22.7	25.4	8	22		1	4		
3	10.3	7.9	17	23.7	24.6	8	22		1	4		
4	10.4	8.6	14 3	23.7	24.2	8	21		1	4		
5	10.7	8.6	13	23.7							Calixin	
6	10.7	8.2	5	33.8	28.8	8	25		5	9		
7	10.9	8.5	5	33.8	31.3	8	27		5	9		
8	10.6	7.8	40	24.7							Manzate	
9	11.0	7.6	13	29.8	27.3	8	24		8	12		
10	11.0	7.0	5	40.7							Bravo	
11	10.8	7.2	2	30.4	35.6	8	31		10	14		
12	10.9	7.2	64	24.8							Manzate /Calixin	
13	11.0	7.0	64	30.8	27.8	8	24		12	15		
14	10.9	7.1	10 6	16.3	22.1	8	19		12	15		
15	10.9	8.7	1	37.4							Manzate	
16	11.1	7.2	3	35.2	36.3	8	32		15	20		
17	11.0	6.8	46	45.4							Calixin	

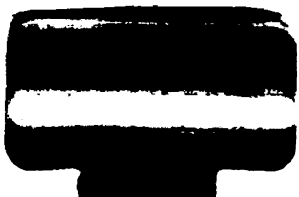
Where: R	=	weekly total rainfall (mm)
E	=	weekly evaporation totals (mm)
E _w	=	weighted evaporation
	=	$\frac{E_n + E_{(n-1)}}{2}$
n	=	week number
A	=	Factor which varies according to climate, soil type and health of the plantation
D	=	Number of days between spray cycles
	=	$\frac{E_w \times 7}{2}$
STD	=	Speed of development totals. Daily maximum and minimum temperatures are used to determine the coefficient of disease development (Ganrey and Meyer, 1972). Not found to be essential in Jamaica with black Sigatoka.
LWS	=	Last week sprayed
NWS	=	Next week sprayed = (D/7)+ LWS
F	=	Fungicide used

Reminders for determining the schedule of fungicide applications for black Sigatoka

- **Always examine all the data before making a decision when to spray.**
 - For example use of absolute evaporation levels would indicate that spraying is necessary almost all the time during the 17 weeks. Between 22-30 mm is favourable for disease development and less than 22 is highly favourable. But the disease data is indicating good response to fungicide applications.
 - Cronshaw data allows early detection of changes in disease intensity and response to fungicide applications but data collection is more tedious and time consuming.
 - YLS is less difficult of the two biological disease data collection method but cannot be relied upon only because it measures stages that are already sporulating and infectious

- Schedules based only upon the climatic forecast system must utilize systemic fungicides only. Therefore, there must be full sensitivity of the entire fungal population to all systemic groups.
- Calculation of spray schedules using by climatic data is based on evaporation. With each application, the average of the actual evaporation totals for the week of the application and the following week must be used. The weighted evaporation for the week prior application cannot be included. This emphasises the greater potency of the fungicide immediately after application. The efficacy in the leaf declines as time passes.
- Reliance on systemic fungicides only jeopardises the long-term sensitivity those fungicides. Protectants should therefore be incorporated.
- When protectant fungicides are substituted, the interval after application in the rainy period must be close to the rate of leaf emission. In healthy fields this can as low as 8 days. In unfavourable disease development conditions the interval may be extended to 10-12 days (depending on the prevailing disease intensity or trends in the disease data).
- Whenever disease or climatic data is not available or unreliable, set spray intervals at the period of activity of the fungicide.
- Extend spray intervals only when conditions are unfavourable for disease development and disease data indicate stable or decreasing trend in disease intensity.
- Other considerations for determining spray schedule:
 - Possibility of rain and availability of aircraft or spray team
 - Effective period of the fungicide being used.
 - Previous or prevailing disease pressure.
 - Effectiveness of the spray applications.





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