Department of Plant, Soil and Environmental Science
DiPSA

Black sigatoka disease model

Simone Orlandini

Department of Plant, Soil and Environmental Sciences
University of Florence

simone.orlandini@unifi.it

Black sigatoka

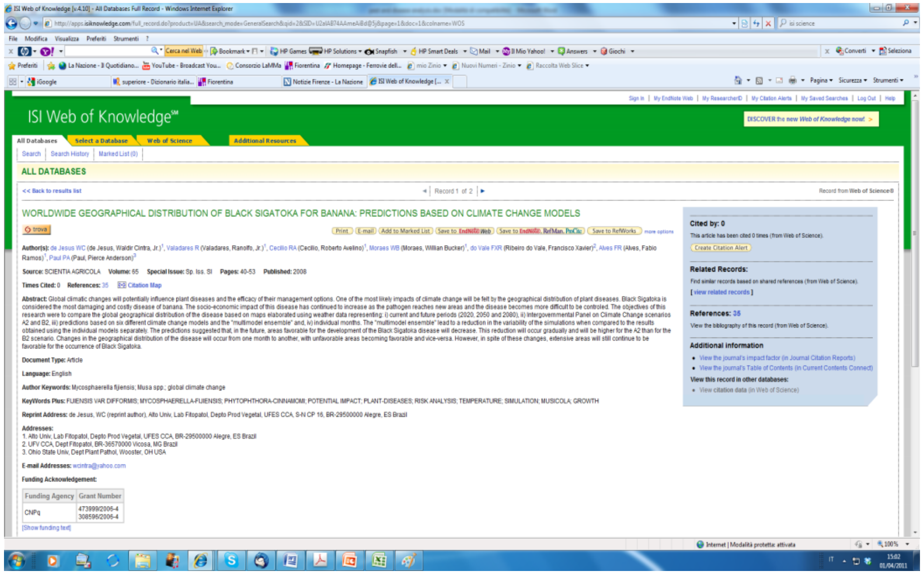
Common name pathogen: Black sigatoka
Kingdom: Fungi
Division: Ascomycota
Class: Dothideomycetes
Order: Mycosphaerellales
Scientific names: Mycosphaerella fijiensis
Host Banana (Musa sapientum)

The disease represents a relevant problem in Caribbean region, with a decreasing of the production of about 50% during critical years. Protection methods can cost about 1500 $/ha/y.

Distribution

The disease caused by the fungus Mycosphaerella fijiensis was first recognized on the South-eastern coast of Viti Levu in Fiji in 1963 (Rhodes 1964).

Subsequently, the disease was reported in the Pacific Islands, Asia, Africa, in Latin America and in La Lima and Honduras in 1972.



ISI Web of Knowledge

ALL DATABASES

WORLDWIDE GEOGRAPHICAL DISTRIBUTION OF BLACK SIGATOKA FOR BANANA: PREDICTIONS BASED ON CLIMATE CHANGE MODELS

Author(s): de Jesus WC (de Jesus, Waldir Cintra, Jr.)[1], Valadares R (Valadares, Ranolfo, Jr.)[1], Cecilio RA (Cecilio, Roberto Avelino)[1], Moraes WB (Moraes, Willian Bucker)[1], do Vale FXR (Ribeiro do Vale, Francisco Xavier)[2], Alves FR (Alves, Fabio Ramos)[1], Paul PA (Paul, Pierce Anderson)[3]

Source: SCIENTIA AGRICOLA Volume: 65 Special Issue: Sp. Iss. SI Pages: 40-53 Published: 2008

Times Cited: 0 References: 35 Citation Map

Abstract: Global climatic changes will potentially influence plant diseases and the efficacy of their management options. One of the most likely impacts of climate change will be felt by the geographical distribution of plant diseases. Black Sigatoka is considered the most damaging and costly disease of banana. The socio-economic impact of this disease has continued to increase as the pathogen reaches new areas and the disease becomes more difficult to be controled. The objectives of this research were to compare the global geographical distribution of the disease based on maps elaborated using weather data representing: i) current and future periods (2020, 2050 and 2080), ii) Intergovernmental Panel on Climate Change scenarios A2 and B2, iii) predictions based on six different climate change models and the "multimodel ensemble" and, iv) individual months. The "multimodel ensemble" lead to a reduction in the variability of the simulations when compared to the results obtained using the individual models separately. The predictions suggested that, in the future, areas favorable for the development of the Black Sigatoka disease will decrease. This reduction will occur gradually and will be higher for the A2 than for the B2 scenario. Changes in the geographical distribution of the disease will occur from one month to another, with unfavorable areas becoming favorable and vice-versa. However, in spite of these changes, extensive areas will still continue to be favorable for the occurrence of Black Sigatoka.

Document Type: Article

Language: English

Author Keywords: Mycosphaerella fijiensis; Musa spp.; global climate change

KeyWords Plus: FIJIENSIS VAR DIFFORMIS; MYCOSPHAERELLA-FIJIENSIS; PHYTOPHTHORA-CINNAMOMI; POTENTIAL IMPACT; PLANT-DISEASES; RISK ANALYSIS; TEMPERATURE; SIMULATION; MUSICOLA; GROWTH

Reprint Address: de Jesus, WC (reprint author), Alto Univ, Lab Fitopatol, Depto Prod Vegetal, UFES CCA, S-N CP 16, BR-29500000 Alegre, ES Brazil

Addresses:
1. Alto Univ, Lab Fitopatol, Depto Prod Vegetal, UFES CCA, BR-29500000 Alegre, ES Brazil
2. UFV CCA, Dept Fitopatol, BR-36570000 Vicosa, MG Brazil
3. Ohio State Univ, Dept Plant Pathol, Wooster, OH USA

E-mail Addresses: wcintra@yahoo.com

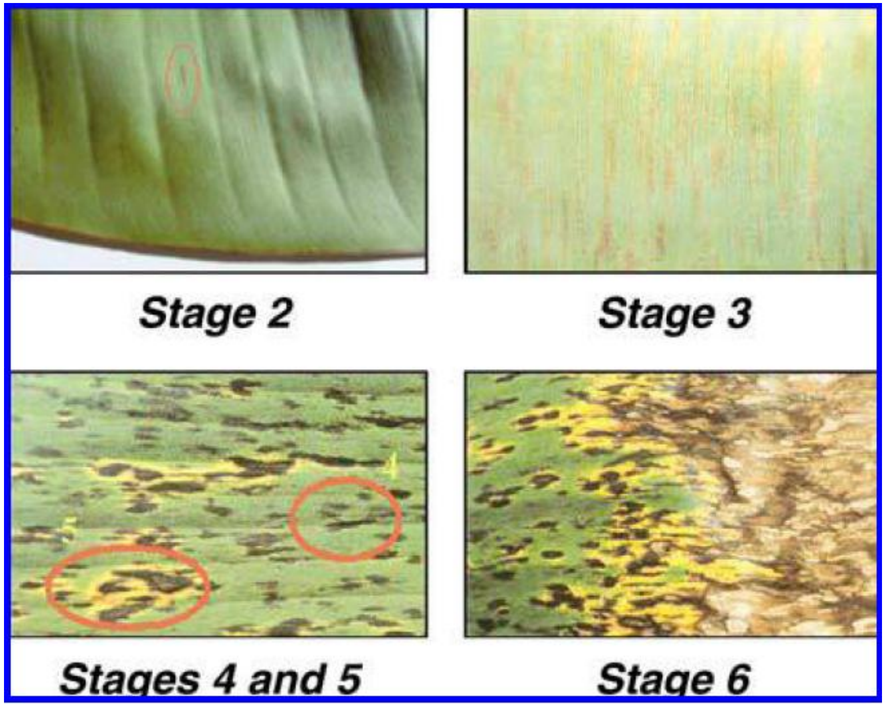
Funding Acknowledgement:

Funding Agency	Grant Number
CNPq	473999/2006-4 308596/2006-4

[Show funding text]

Economic importance

Black Sigatoka is a fungal disease that can cut yields by up to three quarters and reduces the productive activity of banana plants from 30 to only 2 or 3 years. In the last years it has become a global epidemic. The disease spread is an important aspect considering that bananas are a staple food in Latin America and Africa.



Damage

Black Sigatoka is one of the most devastating leaf-destroying diseases. This disease causes significant leaf area reduction, yield losses of 50% or more, and premature ripening.

Control

Black Sigatoka is controlled by frequent applications of fungicides. Usually the banana farms have small dimension and product for local market; the farmers haven't the possibility to afford expensive measures to fight the disease. However, some cultivars of banana are resistant to the disease. The main good practice to contrast the disease spread are: removal of affected leaves and a good drainage.

CAMI project - format for submitting country information

Crop	Economic importance of crop to the nation/community1	Production season (Wet/ Dry/Year round) 2	# Producers	Crop phenology				# Hectare	Major pest/disease	Economic importance of pest/disease to the crop3	Availability of meteorological data4
				Growth period	Vegetative period	Reproductive period	Critical period of crop for pest/disease infestation				

Major pest/disease	Year/time of year infestation	Intensity of infestation5	Problem to be solved with weather related model	Previous experience with the use of model6	Contact Person with e-mail id

Life cycle

- The same conditions required for optimum plant growth are also conducive for development of black Sigatoka. The disease does not develop well under cool conditions or areas of high elevations. Shading can reduce symptoms expression.

- Conidia and ascospores are important in its dispersal. The conidia are mainly water-born to short distances, while ascospores are carried by wind to more remote places (the distances could be limited by their susceptibility to ultraviolet light). Over sixty distinct strains with different pathogenetic potentials have been isolated.

Biological cycle - conidia and ascospores

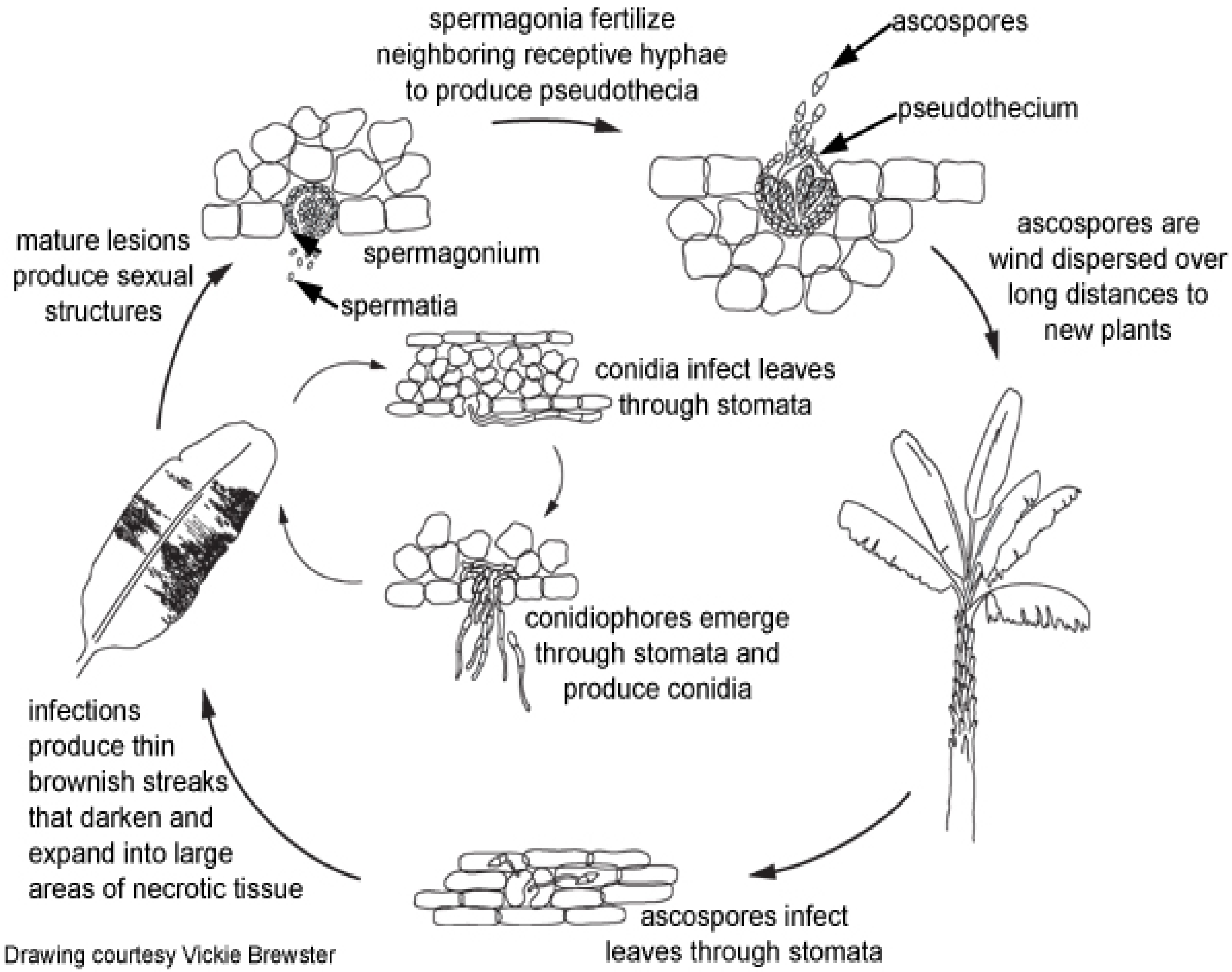
Because M. fijiensis produces relatively few conidia, ascospores are considered to be more important in the spread of black Sigatoka

Conidia become more important during dry periods when disease development is delayed because of the presence of less conducive climatic conditions.

Ascospores are the primary means of dispersal over longer distances within plantations and into new areas, and are the usual means of spread during extended periods of wet weather

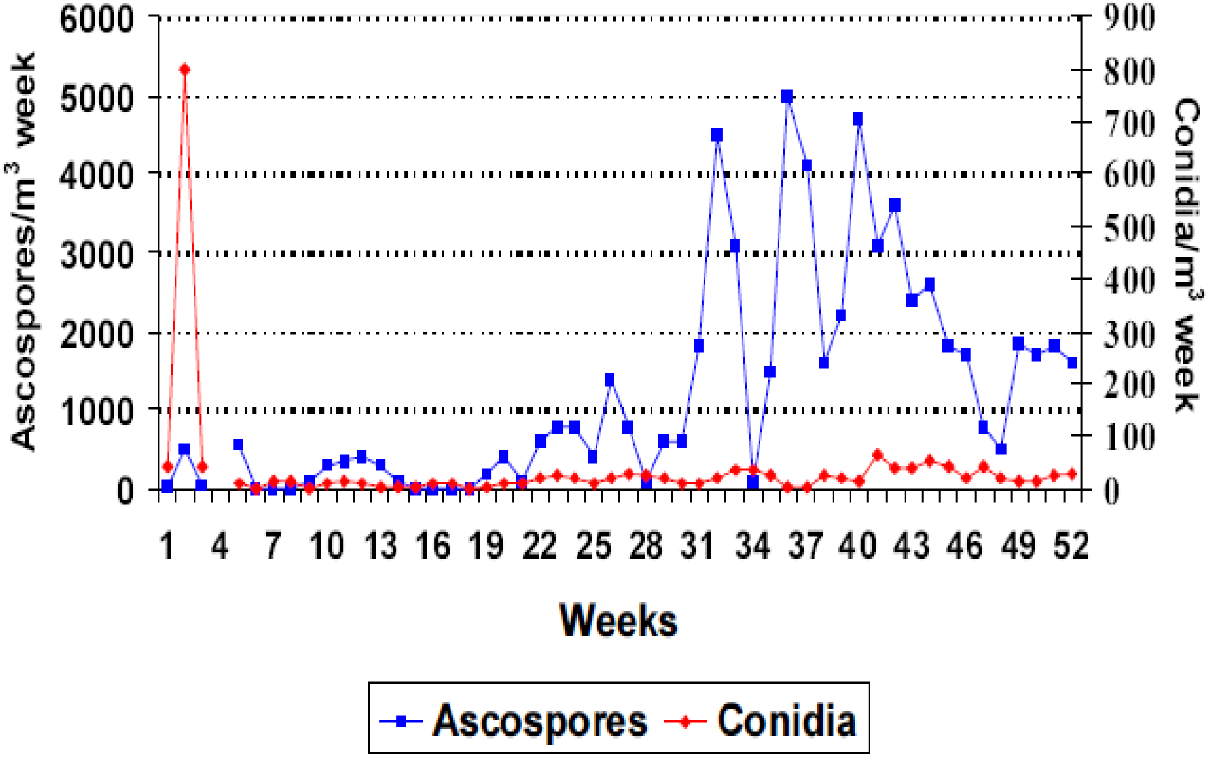
SOURCE: Gauhl, 1994, 2000; Fullerton,1994; Stover, 1980; Jacome et al., 1995; Jeger, 1995, Meredith, 1973

Biological cycle



Black sigatoka - Disease Cycle (Drawing courtesy of Vickie Brewster)

Seasonal variation of ascospores and conidi in the Caribbean zone of Costa Rica



Source: Gauhl,1994

Biological cycle

Ascospores are produced in pseudothecia in mature lesions, which are common on both sides of the leaf surface.

The ascospore release requires the presence of a film of water from rain or dew that imbibes the pseudothecia and results in the forcible ejection of the ascospores through the leaf boundary layer, where they are disseminated by air currents.

During infection the Germ tubes take approximately 48 to 72 h to penetrate the stomata.

Successful infection is promoted by extended periods of high humidity and the presence of free water on the leaves; Maximum germination occurs when there is **free water present**.

THE MODEL

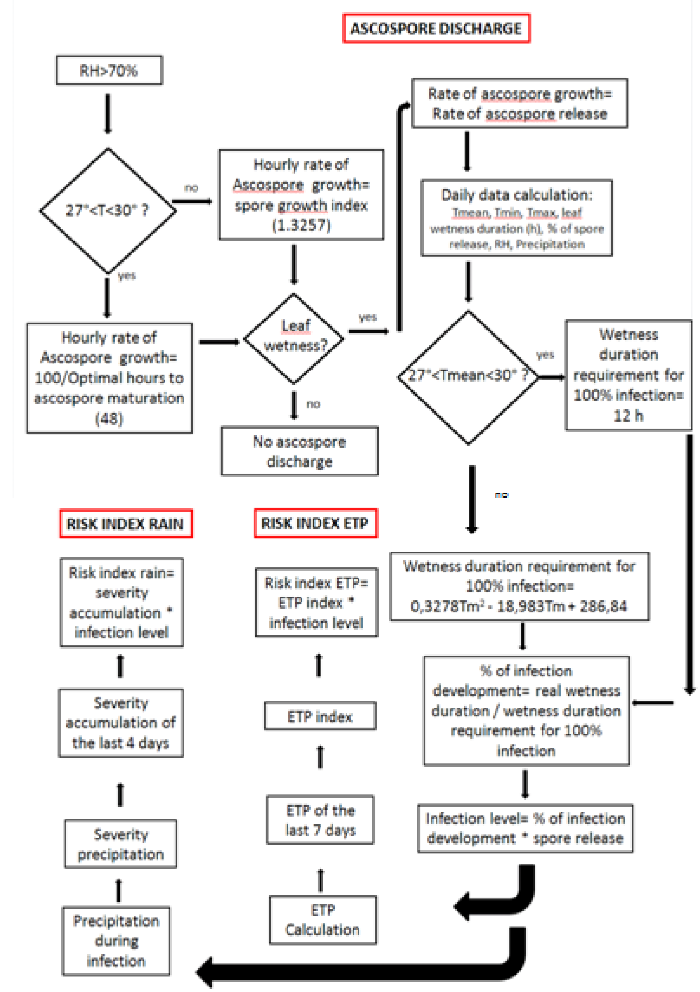
Black sigatoka model

The model describes the infection caused by ascospores produced by pathogen.

MODEL INPUT: hourly mean temperature, hourly relativity humidity and daily or hourly precipitation data.

The model considers different phases

1. ASCOSPORES FORMATION
2. ASCOSPORE DISCHARGE
3. INFECTION
4. THE RISK INDEX



MODEL OUTPUT: risk index of disease

1. Ascospore formation

The model for ascospore formation uses temperature and relative humidity.

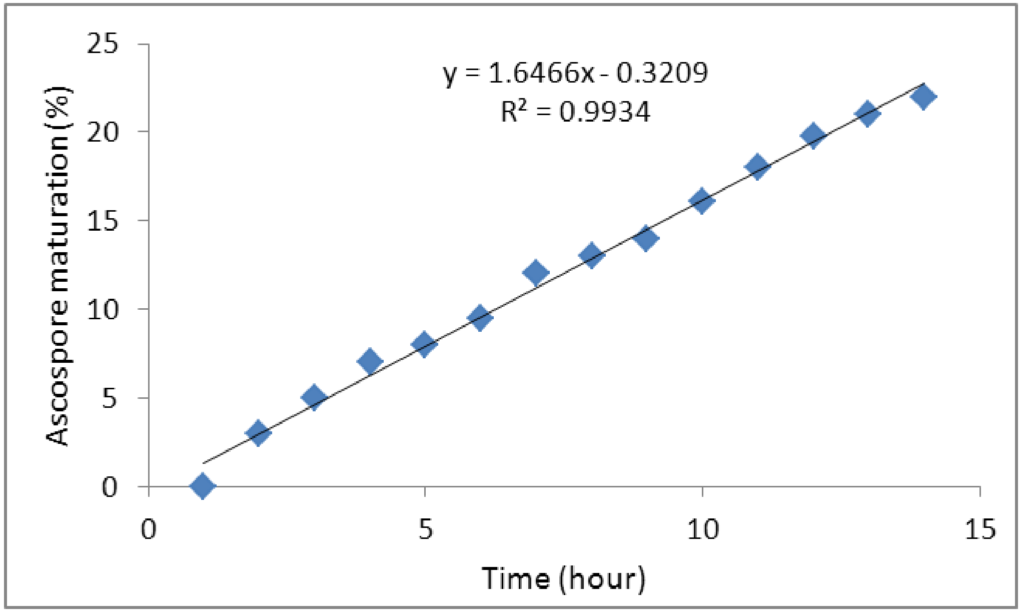
Ascospore formation takes place if:

- Relative Humidity ≥70%
- Optimum temperature is between 27 - 30 °C.

At this temperature the total production of ascospores is reached after 48 hours.

At lower o higher temperature the % of ascospore maturation changes following the function presented in Figure below.

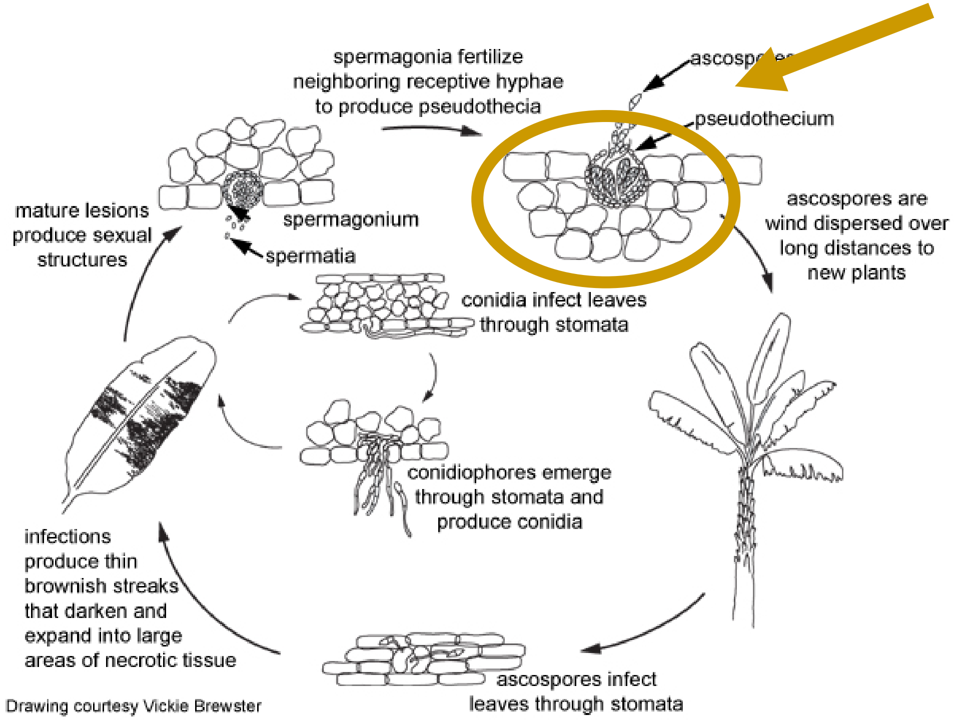
Trend of ascospore maturation for T<27°



Source: Stover, 1980; 1983; Smith et al., 1997, Duthie, 1997

2. Ascospore discharge

This phase requires leaf wetness condition. Due to the lack of leaf wetness duration (LWD) data, an empirical threshold of UR >85% can been considered to estimate LWD



Black sigatoka - Disease Cycle (Drawing courtesy of Vickie Brewster)

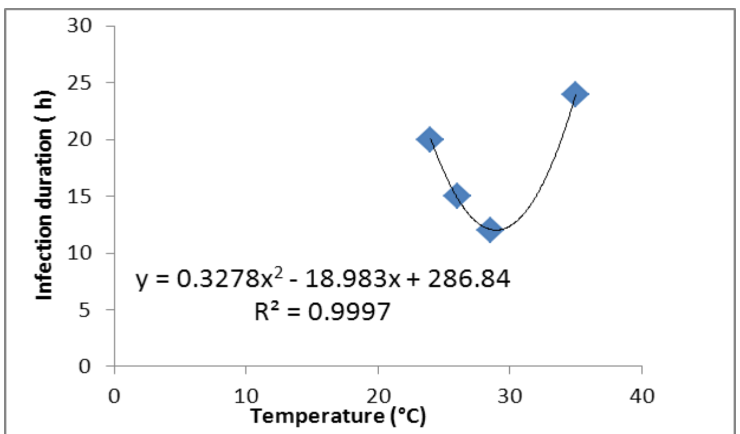
Source: Stover, 1980; 1983; Smith et al.,1997, Duthie,1997

3. Infection

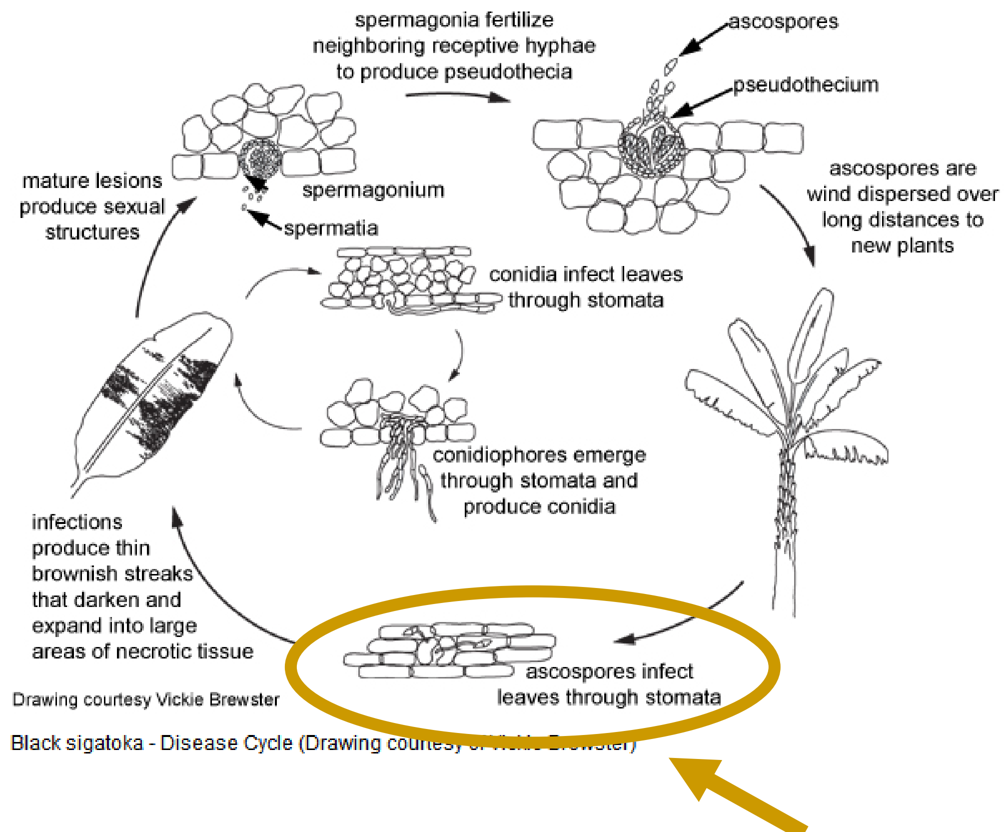
The Infection takes place during periods of leaf wetness.

Under optimum temperature (27°<T<30°C) infection is completed in 12 hours of wet conditions.

If temperature is not optimal, this phase needs more time following the equation shown in figure



Infection duration with different levels of temperature



Black sigatoka - Disease Cycle (Drawing courtesy of Vickie Brewster)

By multiplying the daily infection development per the % of ascospore release, daily level of infection risk was estimated.

Source: Stover, 1983; Chuang and Jeger, 1987; Jacome et al., 1991; Jacome and Aschuh, 1992; 1993

Final Risk Index

The risk index was obtained by combining the infection level obtained with the described method and the risk level due to meteorological conditions. Two methods can be used, the first based on evapotranspiration and the second considering rainfall.

The first method considers **Potential Evapotranspiration**. Hargreaves-Samani formula (1982) was used.

The **risk ETP index** is based on accumulated ETP during the last 7 days

ETP	Risk ETP index
>40 mm	No risk : 0
30≤x≤ 40 mm	Low risk : 1
22<x<30 mm	Average risk: 2
≤ 22 mm	High risk: 3

The **final risk index** is calculated with the following equation:
infection level * risk ETP index

Final Risk Index

The second risk evaluation model uses the **amount of precipitation** during the infection events:

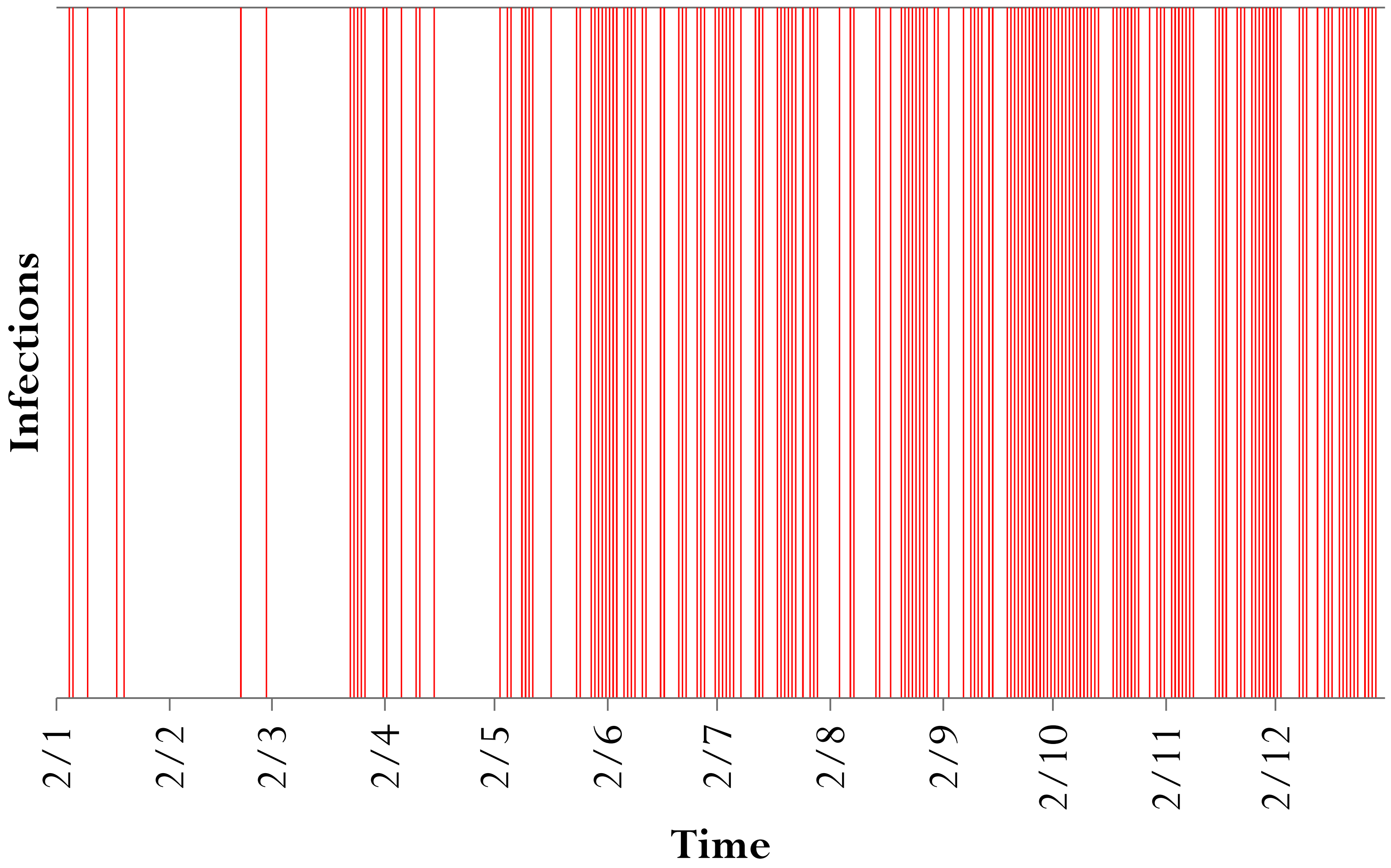
Rainfall	Severity
0 mm	1
0<x<2,5 mm	2
2,5 ≤ x ≤ 5 mm	3
5<x<10 mm	4
≥10 mm	5

The risk is determined considering the accumulation of this severity values for the last 4 days:

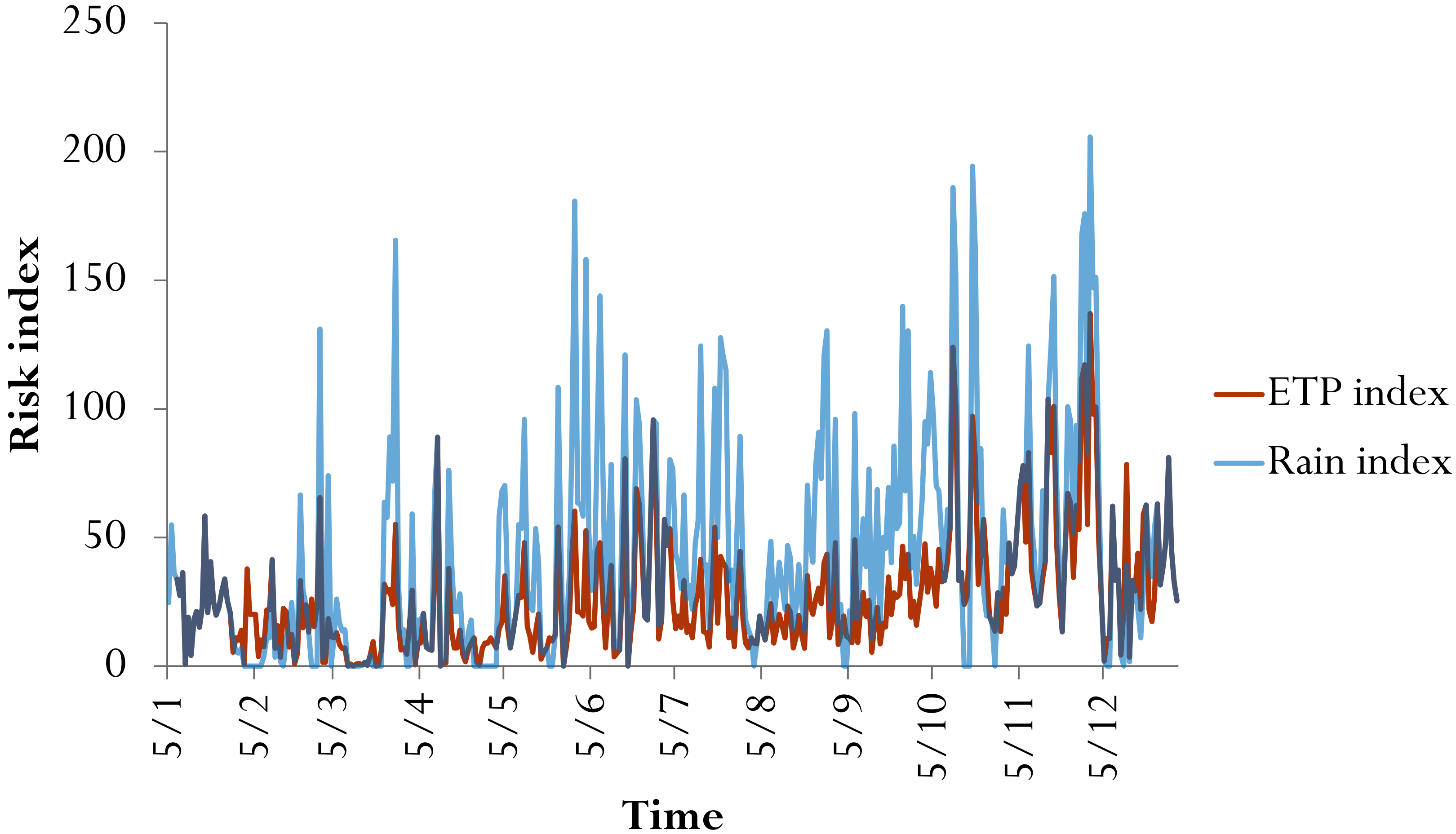
Severity accumulation	Risk rain index
0	No risk: 1
0<x<4	Low risk: 2
4 ≤ x ≤ 12	Moderate risk: 3
>12	High risk: 4

The **final risk index** is calculated with the following equation:
infection level * risk RAIN index.

Outputs – Annual infection events



Outputs - Trend of the risk index



MODEL VERIFICATION

Jamaica

Station	Risk index	Mean Temperature (°C)	Rainfall (mm)
Montego Bay	41,39	26,64	1950
Kingston	5,24	26,25	831

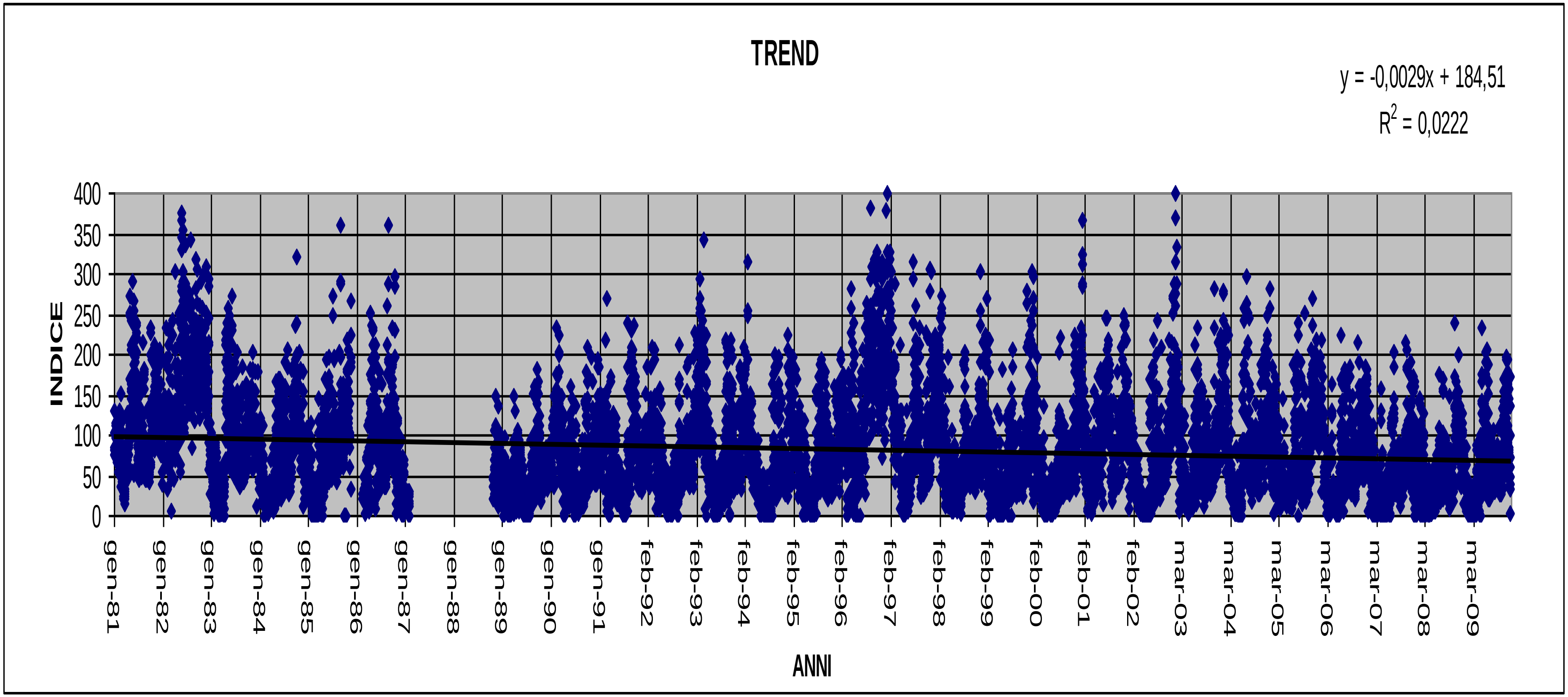
Risk Index

+

-

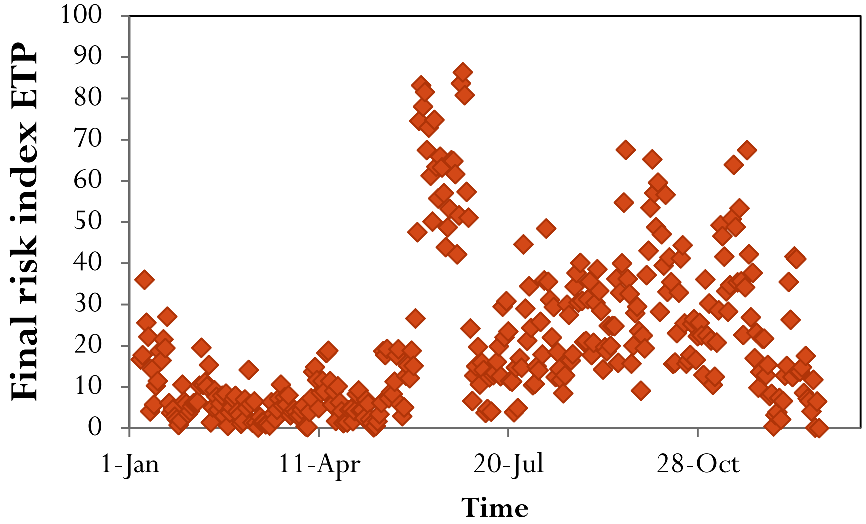
Trinidad e Tobago

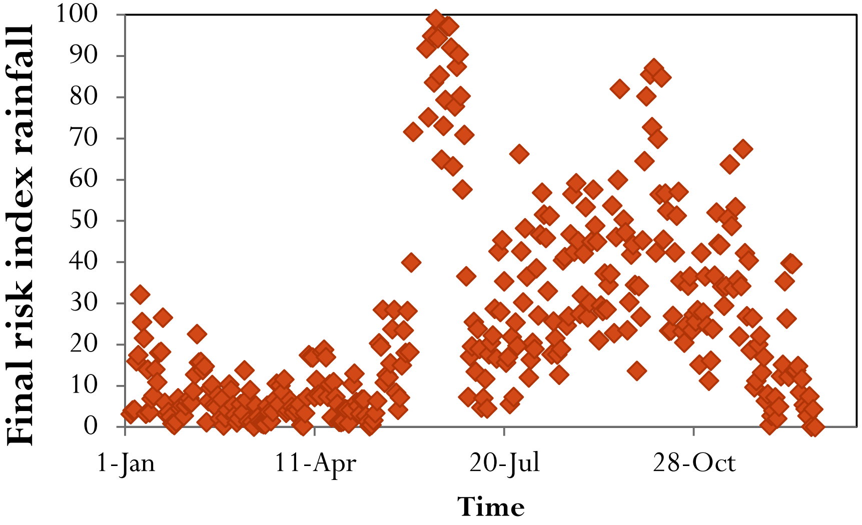
Trend of risk index during the climatic series 1981/2009



S. Lucia

Risk index according ETP and Rainfall 2000/2010





NEXT STEPS

MODEL CALIBRATION, VALIDATION and SENSITIVITY ANALYSIS

Needs of data and information

independent experimental data in several fields or years representing typical climates of the Caribbean regions

Data request

- **geographical position of the farm (Lat, Long, elevation, etc.)**
- **meteorological data (T, RH, LW, Rain) measured close to the farms, to run the model**
- **biological data (banana growth and development, disease infections and severity, risk index in untreated fields)**
- **any other information useful to explain the data (variety, farm dimension, etc.)**

Model bias

$$MBE = \sum (y_o - y_s) / n$$

Mean bias error

Mean bias percentage error

$$MB\%E = 100\left[\sum ((y_o - y_s) / y_o)\right] / n$$

Data correspondence

Root mean square error

Mean asbolute error

Mean asbolute percentage error

$$RMSE = \left\{\left[\sum (y_o - y_s)^2\right] / n\right\}^{0.5}$$

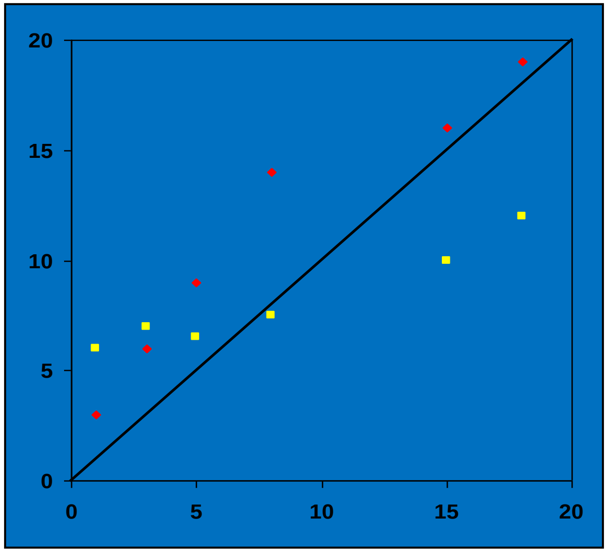
$$MAE = \sum \left| (y_o - y_s) \right| / n$$

$$MB\%E = 100\left[\sum (\left| (y_o - y_s) \right| / y_o)\right] / n$$

Statistical analysis

Correlation analysis (determination coefficient)

	MRE	MR%E	MAE	MA%E	Slope	Intercept	R^2	EF
downy mildew	-0.22	-33.03	1.2	92.39	0.85^{ns}	0.15^{ns}	0.97**	0.92
leaf area	166.14	2.21	456.49	5.26	1.00^{ns}	125^{ns}	0.99**	0.97



	Change (%)										
Year	Temperature						Relative humidity				
	-10	-5	0	5	10		-10	-5	0	5	10
1995	9.29	12.1	16.85	21.46	13.54		1.61	6.79	16.85	37.04	73.87
1996	1.06	2.36	2.26	2.4	4.66		0.36	0.68	2.26	12.22	56.91
1997	4.47	5.5	3.04	3.4	4.59		0.57	2.64	3.04	7.99	16.51
1998	4.18	5.1	3.6	4.94	5.13		0.34	1.4	3.6	22.09	36.87

NEXT STEPS

SOFTWARE AND APPLICATION

BLACK SIGATOKA REPORTING SYSTEM

Home | Update | Obtain Risk | Add New Station | GetData

Common name pathogen: Black sigatoka
Kingdom: Fungi
Division: Ascomycota
Class: Dothideomycetes
Order: Mycosphaerellales
Scientific names: Mycosphaerella fijiensis
Host: Banana (Musa sapientum)

Why Model Black Sigatoka

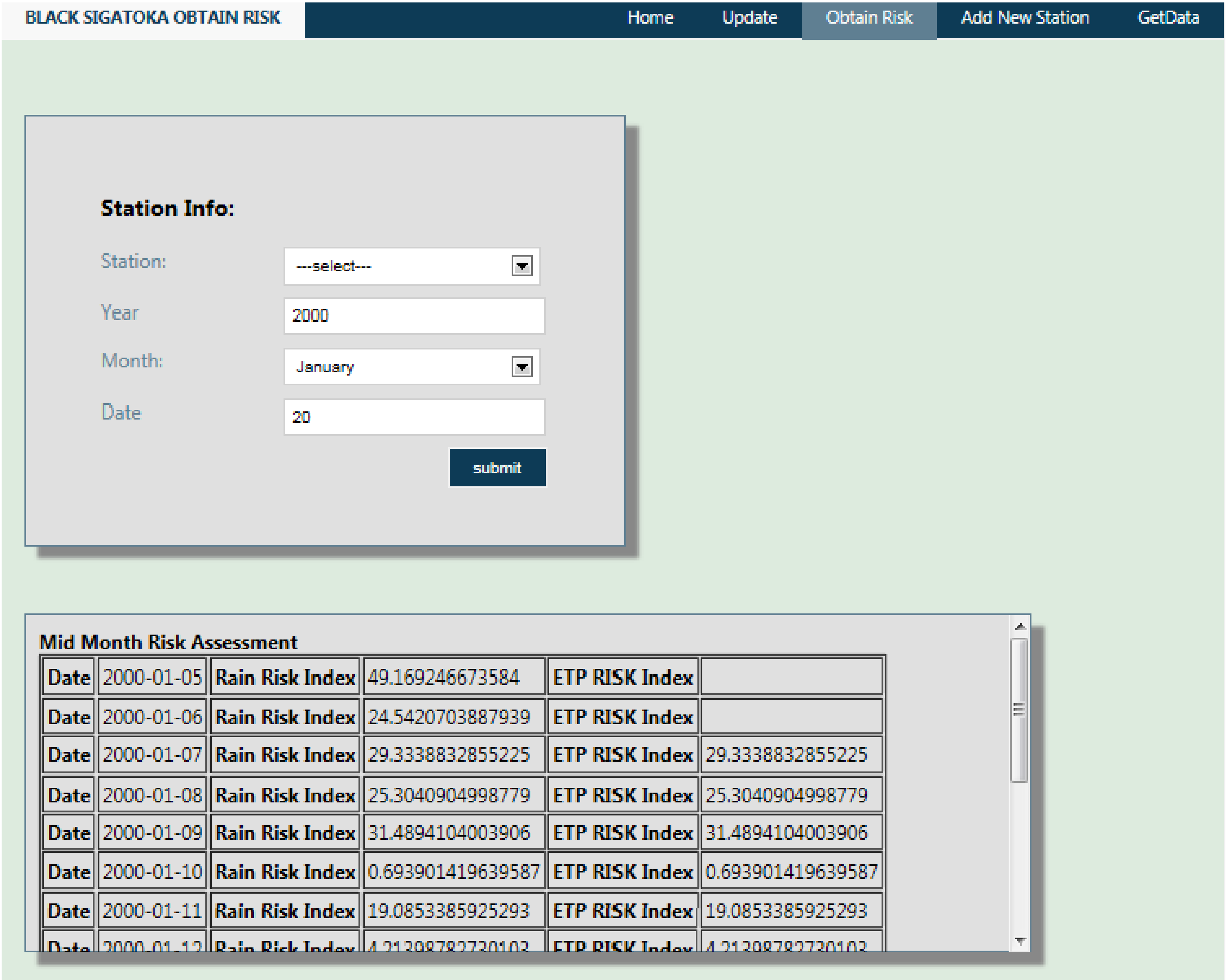
Black Sigatoka also known as black streak disease is caused by ascomycete fungus. This disease has the ability to reduce fruit yield by as much as fifty percent(50%),reduce leaf area and by extension incites premature ripeneing of the crop. In the caribbean context the disease is known to have an enormous effect on banana production and jeproadize small farmers livelihood.

Can it be managed?

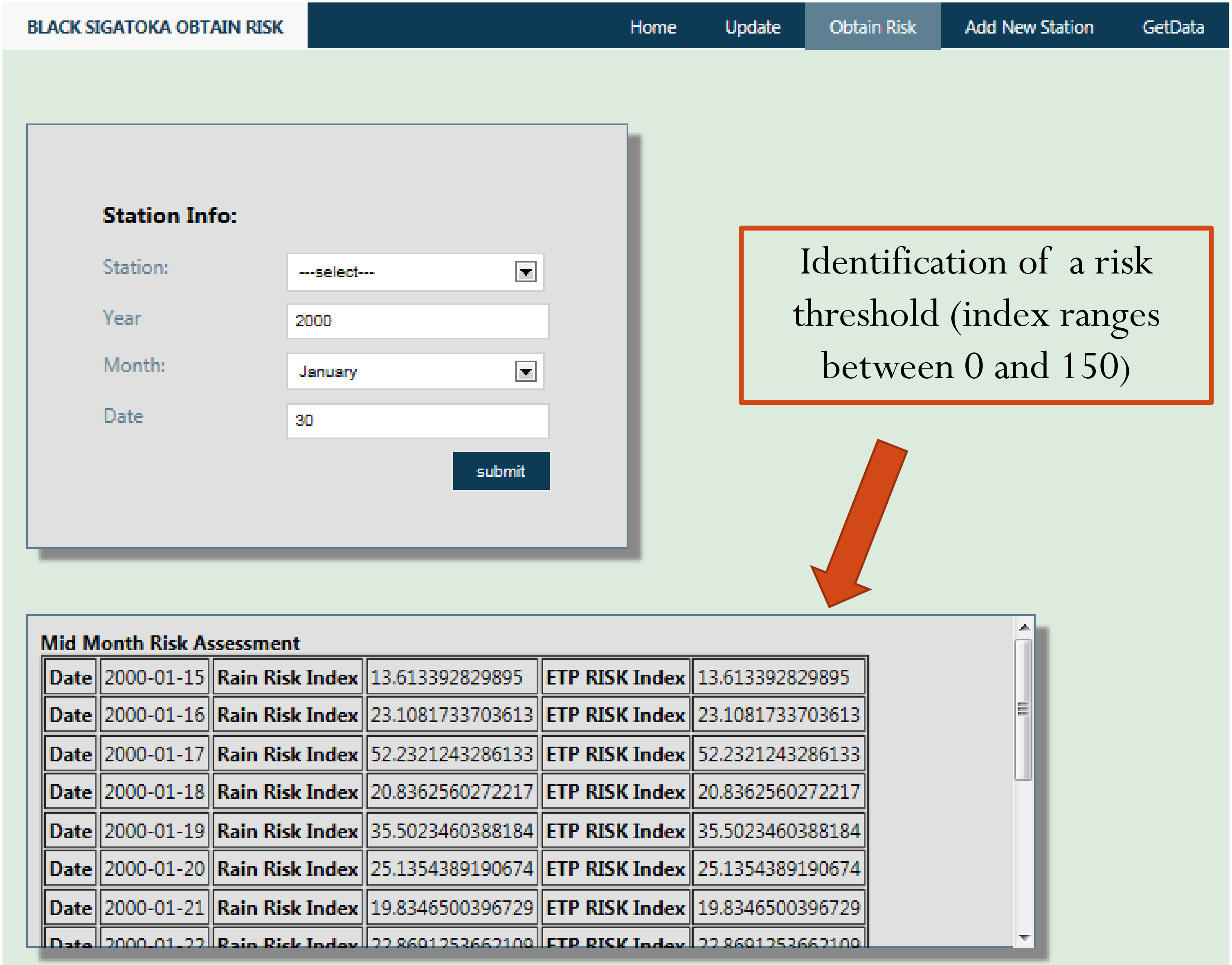
Mycosphaerella fijiensis can be controlled by frequent applications of fungicides, removal of affected leaves, good drainage, and sufficient spacing of plants.

The Program

The Black Sigatoka Monitoring System was created so as to mitigate the effects of the disease by providing risk indexes based on evapotranspiration (evapoartion and plant transpiration) and rainfall. This was conceptualised through the collboraive efforts between the (CAMI)Carribbean Agricultural and Meteorological Initiativ and the Department of Plant, Soil and Environmental Science - University of Florence (Italy)


BLACK SIGATOKA OBTAIN RISK
Home
Update
Obtain Risk
Add New Station
GetData
Station Info:
Station:
---select---
Year
2000
Month:
January
Date
20
submit
Mid Month Risk Assessment
Date 2000-01-05 Rain Risk Index 49.169246673584 ETP RISK Index
Date 2000-01-06 Rain Risk Index 24.5420703887939 ETP RISK Index
Date 2000-01-07 Rain Risk Index 29.3338832855225 ETP RISK Index 29.3338832855225
Date 2000-01-08 Rain Risk Index 25.3040904998779 ETP RISK Index 25.3040904998779
Date 2000-01-09 Rain Risk Index 31.4894104003906 ETP RISK Index 31.4894104003906
Date 2000-01-10 Rain Risk Index 0.693901419639587 ETP RISK Index 0.693901419639587
Date 2000-01-11 Rain Risk Index 19.0853385925293 ETP RISK Index 19.0853385925293

Identification of a risk threshold (index ranges between 0 and 150)



Date	2000-01-15	Rain Risk Index	13.613392829895	ETP RISK Index	13.613392829895
Date	2000-01-16	Rain Risk Index	23.1081733703613	ETP RISK Index	23.1081733703613
Date	2000-01-17	Rain Risk Index	52.2321243286133	ETP RISK Index	52.2321243286133
Date	2000-01-18	Rain Risk Index	20.8362560272217	ETP RISK Index	20.8362560272217
Date	2000-01-19	Rain Risk Index	35.5023460388184	ETP RISK Index	35.5023460388184
Date	2000-01-20	Rain Risk Index	25.1354389190674	ETP RISK Index	25.1354389190674
Date	2000-01-21	Rain Risk Index	19.8346500396729	ETP RISK Index	19.8346500396729
Date	2000-01-22	Rain Risk Index	22.8691253662109	ETP RISK Index	22.8691253662109