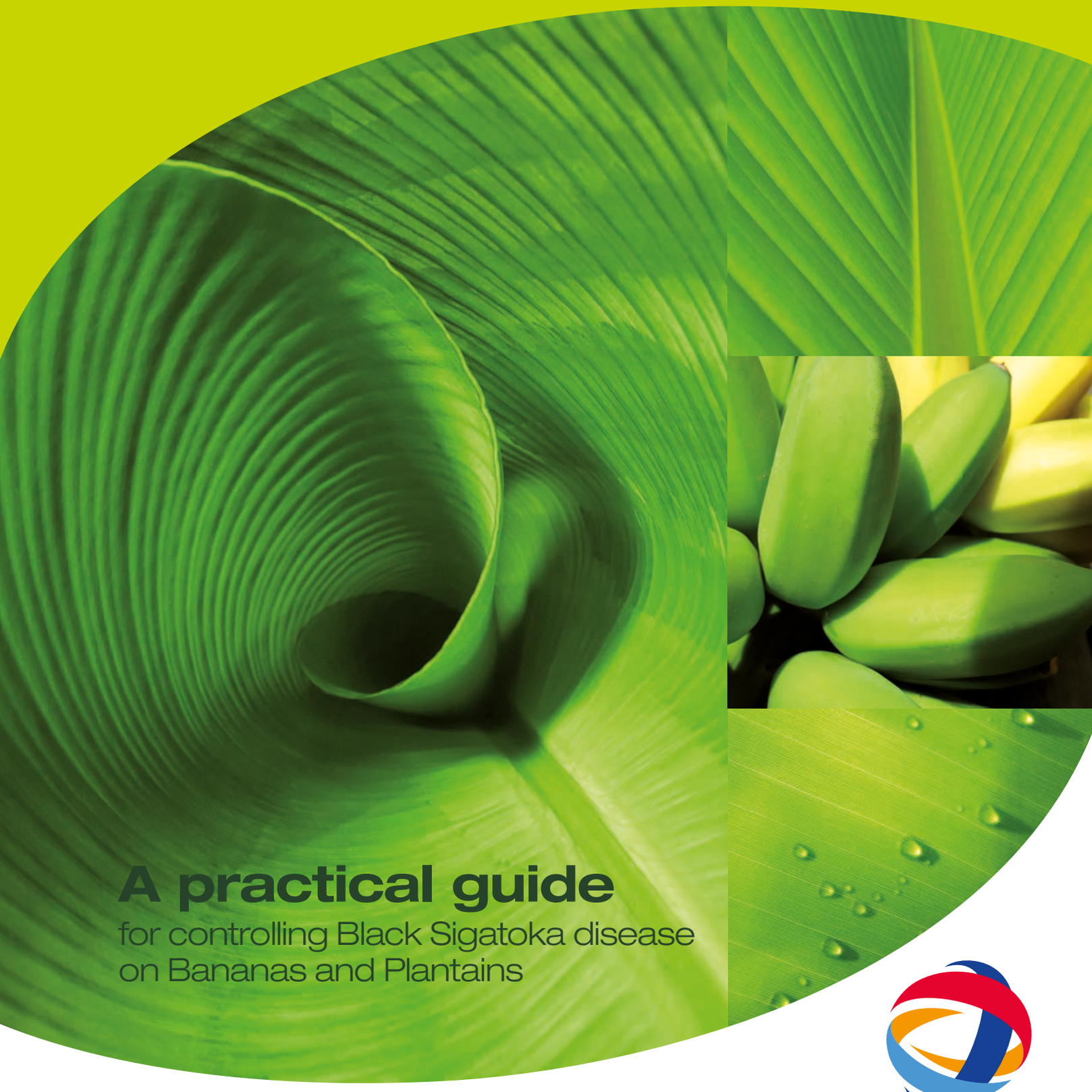
BANOLE® protects...
Crops & the environment

Biodegradable Fungicide Adjuvant
for the control of Black Sigatoka



A practical guide

for controlling Black Sigatoka disease
on Bananas and Plantains

TOTAL

Total Fluides: our commitment

Aware of the necessity of protecting our ecosystems while preserving the yields and the quality of the crops, Total Fluides elaborated a range of crop protection oils with the aim of avoiding the numerous inconveniences linked to the use of classic pesticides.

Total Fluides collaborates actively with research centers, technical institutes and producers for the search for new ways of pests and diseases control in plant protection.

These combined programs allow developing more economic and more rational treatments, which free the crops of pesticides residues and which do not induce the development of resistance of pests and disesases.

Introduction

Banana and plantain cultivations are important socio-economic activities in most of the tropical regions of the world.

Black leaf streak caused by the fungus *Mycosphaerella fijiensis* (Black Sigatoka) is the most destructive leaf disease on Banana. Severe leaf spotting adversely affects photosynthesis capability of the leaves and when few leaves are retained on the plant at harvest time, the fruit will prematurely ripen in the field.

For many years, TOTAL has been closely involved in the control of Sigatoka disease on banana trees with the adjuvant BANOLE®, which was specifically designed to help combat the disease.

BANOLE® is a biodegradable banana spray oil. Its molecular structure is different from conventional spray oils due to a modern manufacturing process. Its physicochemical characteristics for the beneficial action on crop in terms of selectivity and efficiency.

Our technical support, as illustrated by this guide, is available to all BANOLE® adjuvant users and is given by an experienced agronomist, well versed in the diseases of banana cultivation.

This guide has been written to help consultants, technicians and growers involved in Black Sigatoka control and gives clear indications on the evaluation of the disease followed by appropriate recommendations for its management.

TOTAL is a world leader in the Banana Spray Oil market thanks to the many years of experience it has accumulated:

➜ A worldwide experience

BANOLE® is marketed as a specific adjuvant for fungicides applied in aerial or ground applications to control Black Sigatoka disease of bananas and plantains in the following countries:
Belize, Brazil, Cameroon, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, Guadeloupe, Guatemala, Honduras, India, Indonesia, Ivory Coast, Jamaica, Martinica, Mexico, Nicaragua, Panama, Philippines, Porto Rico, St Lucia, Surinam and Venezuela.

History of the disease

The first record of banana leaf spot was from Java in 1902. The next was from the Sigatoka district on the island Viti Levu, Fidji in 1912 where the disease acquired its name.

The pathogen, *Mycosphaerella musicola* LEACH (named Yellow Sigatoka) spread to all major banana growing areas from its Australasia-Southeast Asian base causing serious losses.

A new Sigatoka like leaf spot disease that was more difficult to control than Yellow Sigatoka was first recognised by RHODES in Fiji in 1963 and called black leaf streak. It appeared in the same valley of Viti Levu where *Mycosphaerella musicola* had been identified as a major pathogen of banana cultivation 50 years ago.

In 1964, Leach described the risk of extension of this new disease of «big threat» and was afraid that the abundance of ascospores produced by the pathogen and transported by air movements can lead to the scattering all over the world, in a faster way than for Yellow Sigatoka.

Afterward, in the neighborhood of 1970, the pathogen is identified as *Mycosphaerella fijiensis* MORELET, causal agent of Black Sigatoka and propagates in the Pacific region and in certain regions of Australia and the Southeast of Asia.

Since then, Black Sigatoka propagated in the rest of Asia, Latin America and Africa where it causes a particular concern due to its devastating effect on banana and plantain cultivation.

Countries where Black Sigatoka disease has been detected*

➜ Australia / Oceania

➜ Asia

* Most probable years of introduction

→ Latin America & the Caribbean

→ Africa

Dissemination of the disease

The dissemination of the disease is realized by spores : ascospores for the sexual stage and conidias for the asexual stage.

According to Linneus classification, the causal agent is *Mycosphaerella fijiensis* MORELET for the sexual stage and *Paracercospora fijiensis* DEIGHTON for the asexual stage.

There are two phases in the dissemination of the disease : the release of the ascospores and the conidias on one side and their transport on the other side.

➜ Release

Conidias, when they are ripe, are released by rainfalls or overhead irrigation.

Ascospores are projected out of the perithecias when they split under the action of dew, rainfalls or overhead irrigation.

➜ Transport

Conidias are mainly carried vertically by water. They are responsible for suckers, infestation of bordering plants and re-infestation on the same plant.

Ascospores are carried laterally and vertically by air currents which are responsible for the spread of the disease over large distances.

Installation of the parasite

➜ Germination

Following the transport, conidias or ascospores reach the host plant where, if temperature and humidity are favourable, germination can occur within 6 hours.

➜ Symptoms of the disease

An incubation period follows germination. This non visible phase is followed by the appearance of visible symptoms of the disease, from the first stage until necrosis.

Duration of the development cycle varies according to climatic conditions.

In ideal conditions (absence of treatments and favourable climatic conditions), the complete cycle, from infection until release of new spores takes 18 to 20 days.

In order to observe the development of the disease, 6 stages of the disease have been identified (FOURE scale) :

Stage **1**

Small depigmentation mark of approximately 500 µ long and 200 µ wide, whitish or yellow, progressively turning brown. Those symptoms are not visible in a transmitted light (observed with the light shining through the leaf) and are therefore observable only on the under side of the leaf.

Stage **2**

The depigmentation takes the shape of a generally brown coloured dash, first visible on the inner side of the leaf. This symptom then appears on the upper part of the leaf. This dash then progressively takes on a brown then a black colour on the upper side of the leaf but remains brown on the inner side. It measures generally 4 mm long and 0.5 mm wide. A very high density of stages 1 on the leaves causes stages 2 to appear very quickly, rapidly causing the blackening of the leaf and the appearance of necrotic patches.

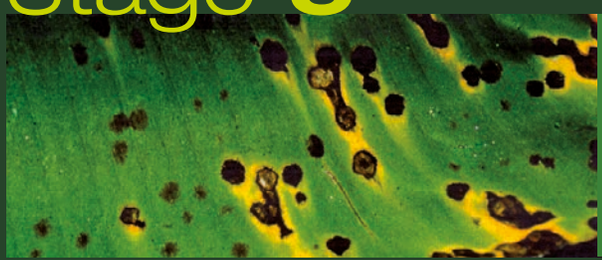
Stage 3

This stage differs from the preceding one in its dimensions. The dash gets longer, broader and may, under certain conditions, reach 20 to 30 mm.

Stage 4

It appears as a brown, coloured mark on the inner side of the leaf, a black one on the upper side, round or elliptical in shape only visible if the density of the dashes of stages 2 and 3 is not much important on the leaf. This mark is sometimes surrounded by a lighter halo. Its dimensions are variable.

Stage 5



The elliptic mark blackens completely. It is generally surrounded by a yellow halo and its centre begins to cave in. The mark has reached its definitive dimensions.

Stage 6

This last stage shows great analogy with the final stage of the Yellow Sigatoka disease. The centre of the spot dries out and takes on a grey shade. The lesion is generally surrounded by a rather narrow black margin edged itself with a yellow coloured fringe.

It is important to note that fungicides applications can only stop the disease in the two first stages of its development and in absence of coalescence. Their action becomes weak on stages 3 and is ineffective beyond.

Control of the disease

The control of the disease is based on the alternative use of contact, penetrant and systemic fungicides of different action site, in order to prevent or delay the build-up of fungal resistance, together with an adjuvant allowing even distribution on the leaves with a low application volume, with or without water.

The mode of action of the fungicides most commonly used in banana cultivation are given in the table «classification of fungicides according to the mode of action» , pages 12 and 13.

Care should be taken when using penetrant and systemic fungicides, as they act in a site specific way on the fungus. When used repetitively, the fungus can become resistant to the fungicide, due to the selection pressure they exert upon the fungus.

Accurate up to date recommendations are available from the FRAC's (Fungicide Resistance Action Committee) Banana Working Group, and can be accessed via the web site (www.frac.info).

Paraffinic Adjuvant

The choice of the adjuvant is important. The objectives to achieve are :

- To allow an even distribution of the fungicide on the selected target (the leaves),
- To slow down the development of the disease by enhancing the incubation period,
- To increase the development time between one stage to another,
- To increase the contact period and the penetration of the fungicide at the cuticle and stomata level.

The Banole® Adjuvant

TOTAL's research centre worked closely with banana growers to develop a new adjuvant which would achieve all these objectives. Due to its innovative characteristics compared to those of a classical spray oil, BANOLE® increases the efficacy of the treatments without inducing phytotoxicity, even at high concentrations, and avoids any danger to human beings and the environment.

These innovative characteristics result in better disease control. The improvement in the field can be explained by the physico-chemical properties of BANOLE® oil:

➜ A better penetration and distribution of the product

The optimum viscosity of BANOLE® allows for better leaf penetration and a better distribution of the application (as observed in the field).

➜ A highly adhesive film

The optimum viscosity of BANOLE® means also low volatibility. Its superficial tension explains the optimum duration of the oily layer on the leaves. Wash-off phenomena, which is responsible for the overconsumption of fungicides, is therefore avoided.

Classification of fungicides according to the mode of action

➜ Fungicides affecting respiratory processes

Action site and/ or effect	Type of fungicide	Action (solo or mixtures)	Use recommendations Observations	Max. number of applications (solo or mixtures)	Spray timing
Multi-sites **Inhibition of spore germination** **Benzene derivates** Chloronitriles Chlorotalonil	Contact	Preventive	Toxic to aquatic fauna incompatible with oils		Leave 2 weeks of interval with oil based treatments
Carbamates **Dithiocarbamates** Mancozèbe Manèbe	Contact	Preventive			No restrictions
Guanidines Dodine	Contact/ Penetrant	Preventive/ Curative	Both, mixtures preferred	6 not more than 33% of total number of sprays	****
Respiratory chain **Inhibition of Mitochondrial complex II SDHI** **(succinate – ubiquinone reductase o succinate deshydrogenase SDH, complex II)** **Carboxamides** Boscalid Fluopyram Izopyrazam	Penetrant Penetrant Penetrant	Curative Curative Curative	Only in mixtures and full alternation	4 not more than 33% of total number of sprays	***
Inhibition of the mitocondrial III complex: external side of the B « Qol » citochrome **Strobilurines** Azoxystrobine Pyraclostrobine Trifloxystrobine	Systemic Penetrant Penetrant	Preventive/Curative Preventive/Curative Preventive/Curative	Only in mixtures and full alternation	3 not more than 33% of total number of sprays	**

➜ Fungicides affecting biosynthesis

Action site and/ or effect	Type of fungicide	Action (solo or mixtures)	Use recommendations Observations	Max. number of applications (solo or mixtures)	Spray timing
Sterol Biosynthesis Inhibitors **Amines** Spirocetalamines Spiroxamine	Penetrant	Preventive/Curative	Mixtures preferred	15 Not more than 50 % of total number of sprays	No restrictions
Nitrogenated heterocycles **Morpholines** Fenpropimorph Tridemorph	Penetrant Penetrant	Preventive/Curative Preventive/Curative	Only in mixtures and full alternation	8 Not more than 50 % of total number of sprays	*

Action site and/ or effect	Type of fungicide	Action (solo or mixtures)	Use recommendations Observations	Max. number of applications (solo or mixtures)	Spray timing
Amin acids biosynthesis Inhibitors (APs)... Anilinopyrimidines Pyriméthanil	Penetrante	Curative	Only in mixtures and full alternation	4 Not more than 50 % of total number of sprays	*
Sterol Biosynthesis Inhibitors (IBS groupe I) Sterol demethylation « DMI »					
Bitertanol	Systemic	Preventive/Curative			
Difenoconazole	Systemic	Preventive/Curative			
Epoxyconazole	Systemic	Preventive/Curative			
Fenbuconazole	Systemic	Preventive/Curative			
Fluzilazole	Systemic	Preventive/Curative	Only in mixtures and full alternation	8 Not more than 50 % of total number of sprays	*
Hexaconazole	Systemic	Preventive/Curative			
Myclobutanil	Systemic	Preventive/Curative			
Tebuconazole	Systemic	Preventive/Curative			
Tetraconazole	Systemic	Preventive/Curative			
Triadimenol	Systemic	Preventive/Curative			

➜ Fungicides acting on cell division

Action site and/ or effect	Type of fungicide	Action (solo or mixtures)	Use recommendations Observations	Max. number of applications (solo or mixtures)	Spray timing
Heterocyclic nitrogens					
Benzimidazoles					
Benomyl	Systemic	Preventive/Curative			
Carbendazime	Systemic	Preventive/Curative	Only in mixtures and full alternation	3 Not more than 33 % of total number of sprays	**
Thiabendazole	Systemic	Preventive/Curative			
Thiophanate - methyl	Systemic	Preventive/Curative			

* Starting preferably at onset of annual disease progression curve

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

*** Preferably at lower disease pressure ; sprays must be separated by at least 8 weeks

**** Preferably at lower disease pressure ; sprays must be separated by at least 6 weeks

Source: Banana working group of the Frac (Fungicide resistance action committee) www.frac.info

➜ An optimum contact duration

This optimum contact duration is due to an homogeneous evaporation according to a narrow distillation range (30 to 40°C, which is an indication of the homogeneity of the product).

➜ Fast penetration

BANOLE®'s fast penetration is due to its high paraffinic content. The molecular structure of BANOLE® allows a fast dissolution of the cuticle protecting the leaves.

➜ Absence of phytotoxicity even at high concentrations Absence of toxicity for the environment

The high unsulphonated residue value number together with a very low acidity indicate BANOLE® is a highly refined adjuvant. In fact, BANOLE® is produced under very strict conditions focusing on the elimination of all toxic molecules (sulphur compounds, polycyclic aromatics…) to protect both the plant and the environment.

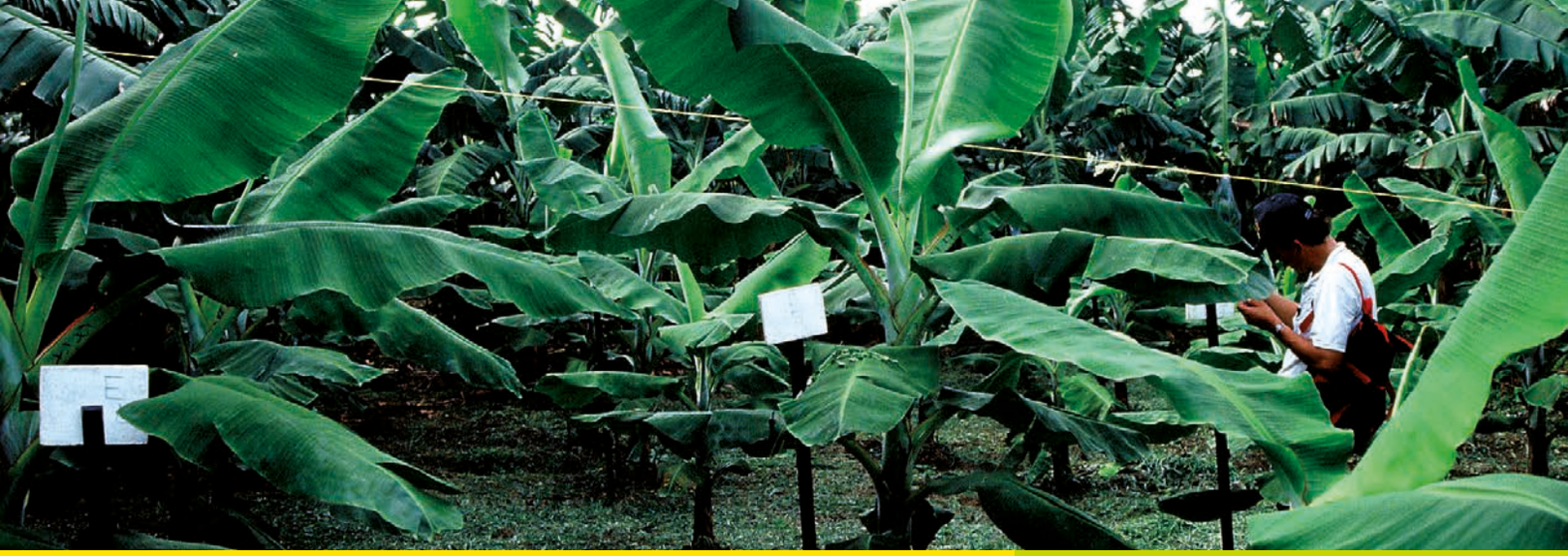
Numerous tests carried out by independent laboratories and institutions have evaluated the non hazardous character of the product :

a) Non toxic on most plants (see biological data)

b) Non hazardous for persons using the product (see toxicological data)
- Mutagenicity test : no irreversible reaction
- Acute dermal/eye irritation : non irritant
- Skin sensitisation test : no reaction

➜ Biodegradability

BANOLE® is biodegradable and non hazardous for the environment. BANOLE® can be used in organic productions.



Biological forecasting

The methodology of the forecasting is based on the analysis of biological descriptors which enable to anticipate the future evolution of the disease and carry out fungicide applications before the crop is affected.

➜ Biological Forecast, Method

The method used is the state of evolution, method designed by CIRAD*. Initially designed to combat Yellow Sigatoka in the Antilles (GANRY & MEYER, 1972-1973), it was latter adapted to Black Sigatoka control in West Africa (FOURE 1982-1988 ; TERNISIEN 1985) and Latin America (BUREAU 1990-1994).

➜ Observation plots

Observations are done on a weekly basis, in a plot where 10 plants, selected at random are observed every week. Observations consist in reading leaves II, III, IV (from the top to the bottom) and note the most advanced stage of the disease on a chart.

The observation plot must be as representative as possible of the behaviour of the disease for a given area.

In a banana plantation, infection is seldom homogeneous. There are sensible areas called « hot spots » where the disease develops faster than in the rest of the plantation.

These areas are not reflecting the development of the disease in the plantation and therefore must be the object of a separate survey. Selecting an observation plot in such an area would lead to a wrong appreciation of the evolution of the disease and therefore contributes to spray in excess.

The number of observation plots is not given according to the surface of the plantation but according to its homogenicity.

Observations are made on first cycle plots in order to dispose of a sensible vegetal material which allows early detection of the disease. When there are already first cycle plots, it is possible to plant a small observation plot (about 40 plants) within the plantation.

Observations continue from stage 10 leaves till flowering, it will be necessary to prepare following cycle observation plots to avoid discontinuities in the observations.

* **CIRAD :** International Center for co-operation in Agronomic Research for Development, Montpellier, France

➜ Observations of the disease

Observations are done on a weekly basis on leaves II, III and IV to detect the presence of the disease as soon as possible.

The research of stage 1 is realized on the inner side of the leaf, on the apical left part in priority, which corresponds to the area first exposed to ascospores infections during the defurling of the leaf.

Stages 2 and 3 may then be observed on both sides of the leaf.

Doing these observations, the operator note, on the state of evolution chart, the most advanced stage present on leaves II, III and IV and gives, together with it, a quantitative estimation by putting the sign + or – if he considers there are more or less than 50 dashes for a considered stage.

It is also interesting, although it is not part of the state of evolution method, to note the youngest leaf spotted to have a quick idea of sanitary level of the plantation.

From the information cited above, it is possible to calculate the state of evolution.

➜ Calculation

The first stage consists in calculating the gross sum (SB).

According to leaf position, each Sigatoka stage has a severity coefficient characterising disease evolution speed according to the following chart :

SIGATOKA STAGE LEAF NUMBER	II	III	IV
1-	60	40	20
1+	80	60	40
2-	100	80	60
2+	120	100	80
3-	140	120	100
3+	160	140	120

On the observation chart, stages of the same category are added together (all stages 1-, then all stages 1+, etc…) then multiplied by their respective severity coefficient.

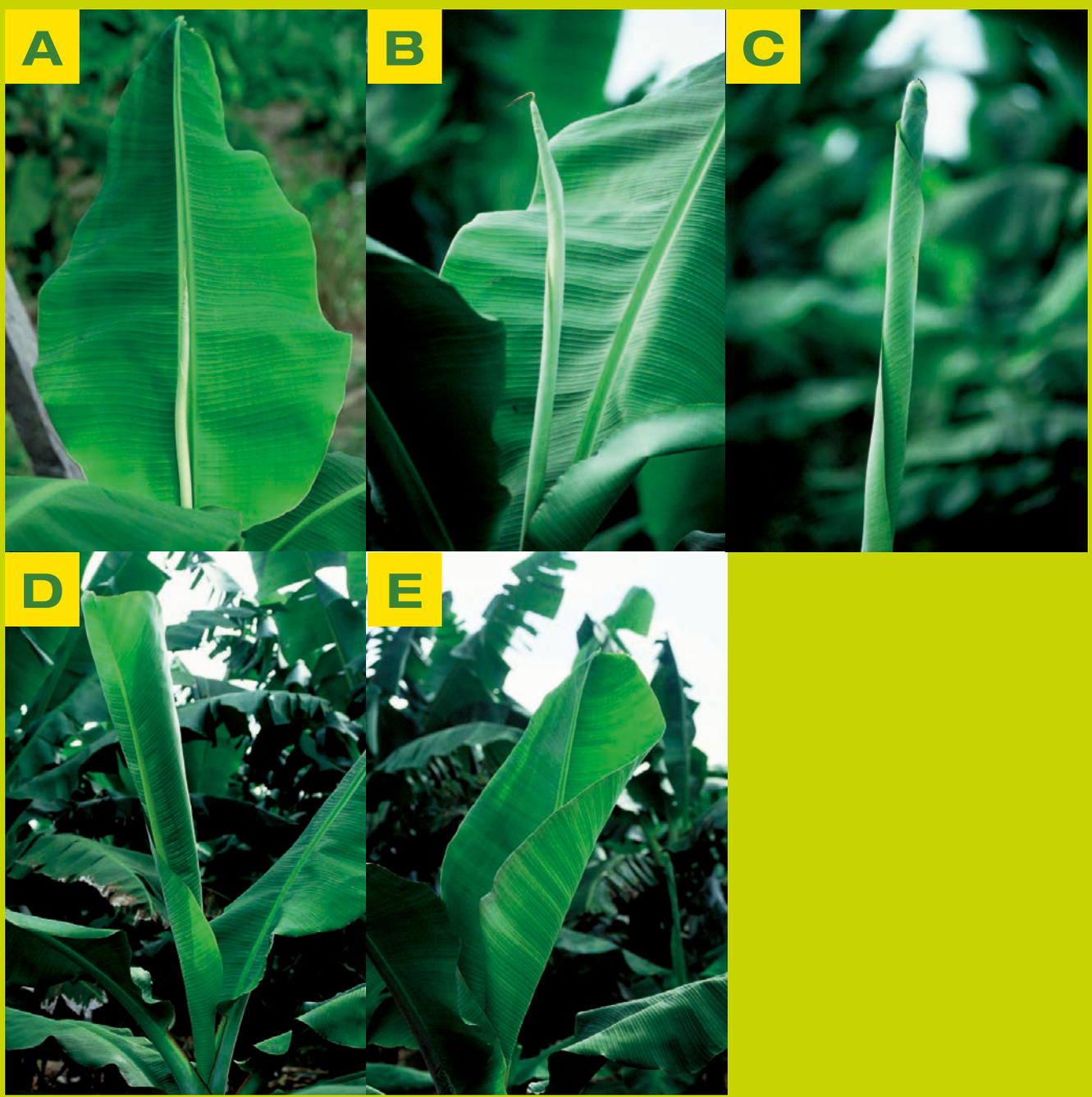
The addition of the data thereby obtained constitutes the gross sum (see example of calculation on the enclosed chart).

➜ Candela correction – Corrected sum

The objective of this correction is to reduce gross sum variations due to the emission of a new leaf between two observations.

In the state of evolution method (see above chart), the difference of gross sum between two leaves is 20. The step of one candela stage to the next one is therefore characterised by a difference of 20/5 (5 cigar stages) = 4.

➜ Candela development stages : A-B-C-D-E



To bring every sum to stage A,
it is necessary to subtract the following quantities :

4 for stage B (noted 0.2)
8 for stage C (noted 0.4)
12 for stage D (noted 0.6)
16 for stage E (noted 0.8)

In practise, we multiply, for each plant observed, the decimal part of the « cigar stage » by the number of leaves with a note different from 0.

The total of these values, multiplied by 2, gives the corrective term for the state of evolution, CE. Corrected sum (SEV) is then SB-CE.

➜ Foliar emission correction : state of evolution

The final state of evolution value (EE), is the product between SEV and $\overline{REFi}$.

State of evolution is the expression of a speed. Sigatoka stage and leaf number are correlated to time through foliar emission.

Foliar emission rhythm is given by the difference between actual foliar emission (EFA) and past foliar emission (EFP).

REFi represents the average foliar emission rhythm for 10 days.

$$REFi = \frac{\Sigma.REF}{nb} \times \frac{10}{n}$$

with : **Σ**. REF : REF sum per plant
N : interval in days between two observations
Nb : number of plants observed

Biological forecasting Black Sigatoka

PLANT N°	EFP	EFA	REF	CE	Leaf position			Youngest leaf streaked	Youngest leaf spotted	Stages	Nb of leaves infected			Notes obtained		
					II	III	IV				II	III	IV	II	III	IV
A3	16.2	17.4	1.2	8		1+	1-	3	8	1-	1		7	60		140
B8	16.6	17.8	1.2	8			1-	4	8	1+	1	1	1	80	60	40
C5	15.2	16.8	1.6	16		2-	1-	3	8	2-		1			80	
D9	16.2	17.4	1.2	4			1-	4	8	2+		1			100	
E2	15.4	16.8	1.4	8			1-	4	8	3-						
F7	16.2	17.2	1	4	1-		1-	2	10	3+						
G4	15.4	16.6	1.2	6			1-	4	9							
H8	16.4	17.4	1	-				5	11							
I5	16.8	18.2	1.4	4	1+	2+		2	12							
J9	15.0	15.8	0.8	8			1+	4	9							
S. REF			12								TOTAL (560)			140	240	180
S. CE				66												
N			7													
REFi			1.7		Average			4.2	9.2							

CE = 132 (66 x 2)
SB = 560
SEV = (SB-CE) = 560 – 132 = 428

$\overline{REF}$ + REFi/2 = $\overline{REFi}$
1.8 + 1.7/2 = 1.8

EVOLUTION STATE = SEV X $\overline{REFi}$
EE = (428 x 1.8) = 770

➜ Interpretation of the results

Every week, state of evolution values are plotted on a graph in order to establish a curve which allows to follow the development of the disease in time, and anticipate its probable evolution.

It is then the trend of the curve which will provoke the decision to spray. In practise, there is no critical threshold at which the decision should be taken .

A significant increase of the state of evolution from one week to the other, even if the values remain rather low, must be taken into consideration in order to keep the preventive aspect of the system.

Conclusion

Black Sigatoka Control Strategy is more effective when applied preventively, using a forecasting system based on biological and climatological data.

The biodegradable paraffinic adjuvant Banole, due to its physico-chemical characteristics, allows an even distribution of the mixture on the leaves. Its narrow distillation range, associated with an appropriate viscosity allows a synergistic effect with both contacts and systemic fungicides used for Sigatoka control.

Furthemore, its high unsulphonated residue level, associated with very low aromatic compounds give the user an insurance of production quality, while respecting the environment.

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➜ WEB SITES :

www.totalspecialfluids.com

www.cirad.fr (International Centre for Cooperation in Agronomic Research for the Development)

http://bananasbiodiversityinternational.org (Research group on banana biodiversity)

www.frac.info (Fungicide Resistance Action Committee)

Banole® distributors

Total affiliates

➜ TOTAL BRASIL
Rua Gomes de Carvalho, 1356 Conjunto 71
04547 - 005 – Vila Olimpica
São Paulo – SP Brazil
Tel: +55 (11) 3848 2600 - Fax: +55 (11) 3849 7723
Cel: +55 (11) 99346 0909
Contact: fabiane.astolpho@totalbr.com.br

➜ TOTAL CAMEROUN S.A.
589, Boulevard de la Liberté Akwa – Douala
B.P. 4048 Douala – Cameroun
Tel: (+237) 33 42 63 41 – Fax: (+237) 33 42 84 58
Contact: francois.jabea@total.cm

➜ TOTAL CARAÎBES
Zone Industrielle Californie
BP 436 Le Lamentin
Tel: +(596) 596 509 369 - Fax : +(596) 596 507 655
Contact: amandine.delorme@total-caraibes.com
www.total-caraibes.com

➜ TOTAL CÔTE D'IVOIRE S.A.
Immeuble NOUR AL HAYAT – Abidjan Plateau
01 B.P. 336 Abidjan 01 – Côte d'Ivoire
Tel: +(225) 20 30 06 06 - Fax : +(225) 20 33 42 08
Cel: +(225) 07 05 89 63
Contact: jean-modeste.tanoh@total.ci

➜ TOTAL PETROLEO COSTA RICA S.A.
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Cel: +(506) 8843 7118
Contact: manfred.hubner@totalcr.com

➜ TOTAL GUADELOUPE
Imm. ADONIS – BP 2142 – Jarry Cedex
Guadeloupe
Tel: +590 590 261 727 - Fax: +590 590 387 411
Contact: jean-marc.lasserre@totalguadeloupe.com
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Guadalajara, Jalisco, México
Conm: +(52) 33 3812 2300 Ext 375 Fax: Ext 335
Cel: +(52) 33 1466 7483
www.total.com.mx
Contact: eduardo.munoz@total.com.mx

➜ TOTAL (PHILIPPINES) CORPORATION
Penthouse, Total Corporate Center
1012 Triangle Drive, North Bonifacio
Bonifacio Global City, 1201 Taguig City
Philippines
Tel: +(632) 849 0888 - Fax: +(632) 849 0989
Contact: mike.doce@total.com

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Direct: +(1) 787 749 7782
Tel: +(1) 787 783 4625 - Fax: +(1)787 783 0407
Contact: carlos.arroyo@tpprc.com
www.total.com.pr

➜ TOTAL R&M TRINIDAD AND TOBAGO
25th Warner Street - Newtown, Port of Spain
Trinidad & Tobago
Tel: +(1-868) 628-4265, 0833, 2906
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www.lubrisa.com

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92069 Paris La Défense Cedex
France
Tel : + 33 1 41 35 59 72
Fax : + 33 1 41 35 51 34
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