MANAGEMENT OF BLACK SIGATOKA IN CAMEROON

MANEJO DA SIGATOKA NEGRA NA REPÚBLICA UNIDA DOS CAMARÕES

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SUMMARY

In Cameroon, *Mycosphaerella fijiensis* was reported for the first time in 1981 and the control against black leaf streak disease represents the highest production cost which can attend up to 10% of total production cost. In fact, the epidemiological context which exists in Cameroon is particularly favourable to the disease notably in the rainy season from April to November. Towards the end of the 80s, a forecasting system using biological descriptors was elaborated and applied with success, reducing the number of treatments to 12 – 14 per year. Since 1996, the development of fungicide resistance lead, even if the levels of resistance fluctuate, to the progressive abandon of this rational strategy at the expense of systematic control methods. Thus in 2005, about 40-50 treatments were done on most of the plantations and the control programme was based on the ratio of 80% of contact fungicides and 20% of systemic and penetrant fungicides. This evolution has lead to an important increase of the cost of disease control, but also to an increase of negative environmental effects. In those conditions, research conducted in Cameroon is aimed to:
* Experiment fungicides having less negative environmental effects.
* Adapt control strategies to the situation of fungicide resistance. Experiments realised in 2005 have shown that chlorothalonil enabled a very good control of the disease, even in the rainy season. New strategies where the proportion of chlorothalonil would be rationalized to a minimum are presently evaluated.
* Evaluate the possible reversibility of fungicide resistance, in order to reintroduce a the more sustainable forecasting strategy. The hypothesis is that the fluctuations observed in the resistance frequency to systemic fungicides could result from a lower fitness of resistant strains, which could be counter- selected in the absence of the fungicide selection pressure and/or gene flow between the treated and the untreated areas.

Keywords: Mycosphaerella fijiensis, forecasting system, Chemical control, fungicide resistance.

INTRODUCTION

Black Sigatoka (Black Leaf Streak Disease, BLSD) is one of the main parasitic constraints in agro–industrial plantations of dessert bananas. This disease has an important impact, since all banana varieties cultivated in agro–industrial plantations belong to the Cavendish sub group which is highly susceptible to BLSD (Fouré *et al*., 1990). On susceptible varieties of bananas and plantains, BLSD provoke the appearance of leaf necrosis, and the attack of the pathogen (*Mycosphaerella fijiensis* Morelet) can lead to important reduction in photosynthetic activity and yield losses which vary between 10 and 100%. However, the most important effect of the disease is indirect, for bunches harvested on highly affected plants have their green life reduced and cannot be exported (Stover, 1974). This foliar disease is present in the major banana producing countries in the world (Pasberg-Gauhl *et al*., 2000), and the intensive cultivation of dessert banana for exportation can only be achieved through intensive chemical control.

Control of BLSD is essentially based on aerial application of fungicides to protect the young leaves from contamination. In most production countries, fungicides are applied systematically following a predetermined framework (Marin *et al*., 2003). In some cases, forecasting systems have been established and treatments are decided as a function of the degree of evolution of the disease (Fouré, 1988; Bureau, 1990). Three types of fungicides are used: (i) contact fungicides which have only preventive effect (mancozeb or chlorothalonil); (ii) penetrating fungicides (inhibitors of ergosterol biosynthesis of group 2 and pyrimethanil) which have a low curative effect; and (iii) systemic fungicides (antimitotics - benzimidazoles -, inhibitors of ergosterol biosynthesis of group 1 – triazoles - and respiratory inhibitors – strobilurines -) which have a strong curative effect. Moreover, these fungicides particularly the systemic ones are used in oil (or in an oily emulsion) for these oils enable a better distribution of the fungicide, limiting it from being wash away by rainwater, and particularly because they have a fungistatic effect. Finally, in the treatment strategies, fungicides are used in alternation or in mixtures (Marin *et al*., 2003). Depending on prevailing climatic conditions which determine parasitic pressure, the susceptibility of the parasite to systemic fungicides and the control strategy used, 12 to 60 treatments per year are realized for BLSD control.

HISTORY OF BLACK SIGATOKA CONTROL IN CAMEROON

1. Development of a forecasting system

Mycosphaerella fijiensis was reported for the first time in Africa, in Gabon, in1980 and further in Cameroon in1981 (Fouré, 1984). Rapidly BLSD has reached all the banana commercial farms, and the control against this disease represents today the second highest production cost which can attend up to 10% of total production cost (0,55 USD/box). In fact the epidemiological context which exists in Cameroon, particularly in the Mungo division where most of the banana plantations are located, is very favourable to the disease (Fouré and Moreau, 1992), notably in the rainy season from April to November (figure 1). Towards the end of the 80s, a forecasting system using biological descriptors was established (Fouré, 1988) and enabled a good control of the disease with only 12-14 applications per year using systemic fungicides (figure 2).

Figure 1. Weekly rainfall observed in the Moungo division, over a 1 year period.

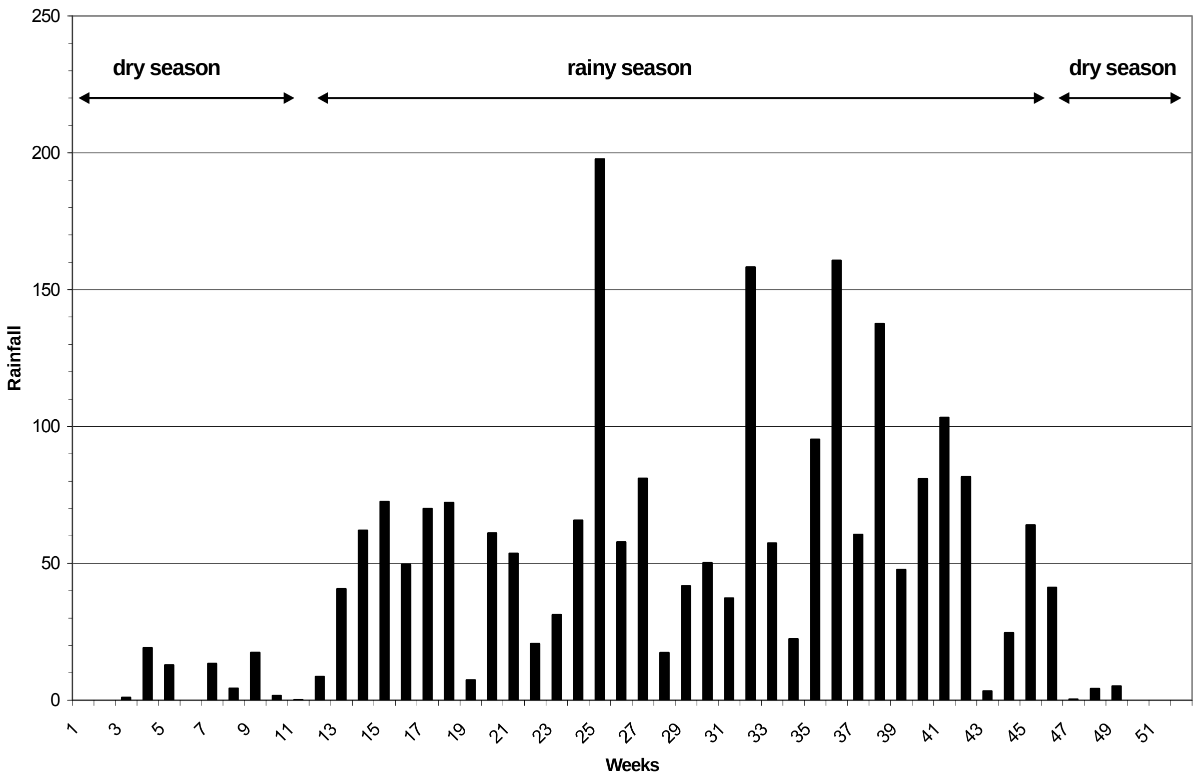
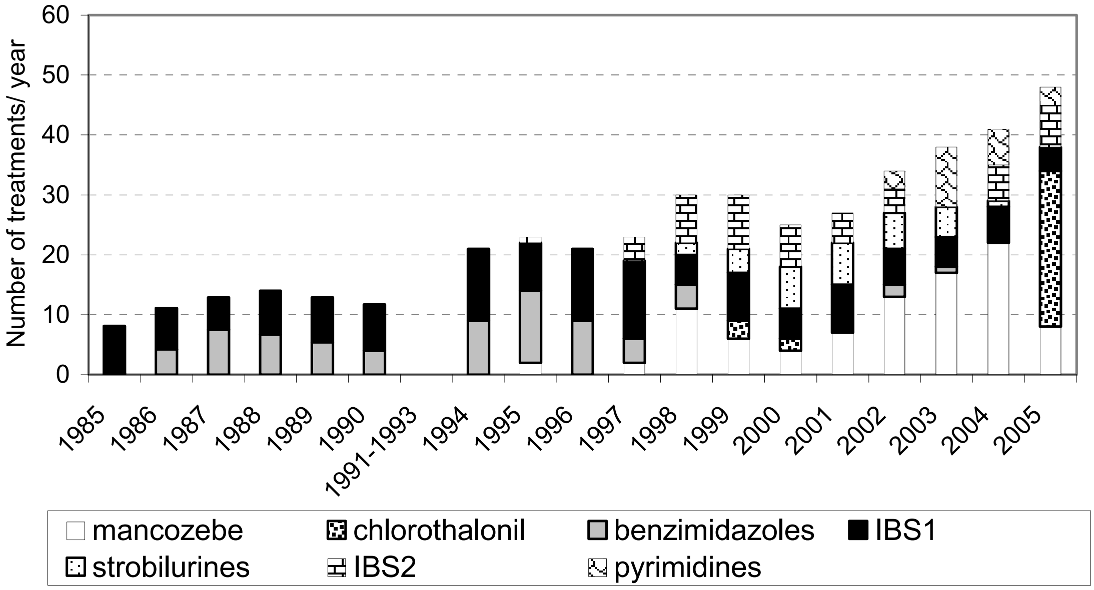


Figure 2. History of fungicide use in Cameroon, for BLSD control



This forecasting system relies on specific technical factors (i) the timing of decisions; (ii) the timing of applications; (iii) the treatment efficacy and (iv) the organization of control (de Lapeyre de Bellaire *et al*., 2000).

1.1. Timing of decisions

The biological forecasting system (Fouré, 1988) is based on the early detection of new attacks through the calculation of a parameter called the Stage of Evolution of the Disease (SED). In this method, 10 plants are selected in a plot and are observed every week to provide continuous information about the development of the disease. The youngest leaves of the banana tree (leaf 2, 3 and 4) are inspected every week and the most advanced stage of the disease is scored for each leaf. As shown in table 1, a coefficient is attributed to each different (leaf number)/(stage of the disease) associations, and depends also on the density of infection. This coefficient is characteristic of the speed of evolution of the disease.

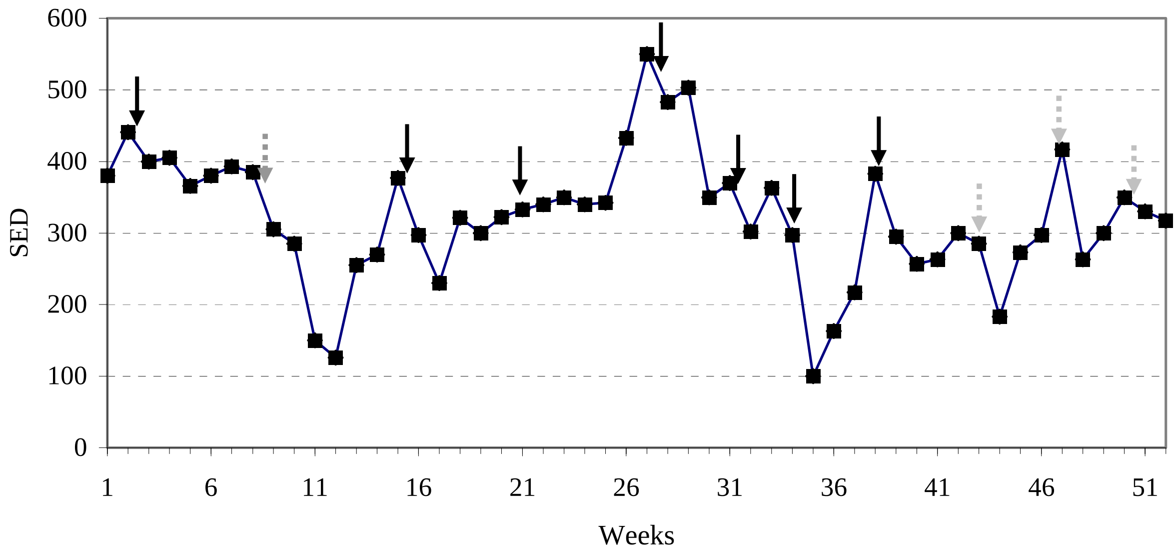
Table 1. Coefficients attributed to the different (leaf number) / (stage of the disease) association, for the calculation of the Stage of Evolution of the Disease (SED)

Stage of the disease[x]		Leaf II	Leaf III	Leaf IV
1	-	60	40	20
	+	100	80	60
2	-	100	80	60
	+	140	120	100
3	-	140	120	100
	+	180	160	140
4	-	180	160	140
	+	200	200	180
5	-	220	200	180
	+	260	240	220
6	-	260	240	220
	+	300	280	260

[x] for each stage of the disease, the coefficient attributed depends on density of symptoms: (-) if less than 50 lesions are observed on the leaf ; (+) if more than 50 lesions are observed on the leaf

The sum of all the corresponding coefficients (SC) is calculated every week over all leaves observed on the 10 plants. A second observation is carried out on those 10 plants noting the Foliar Emission Rate (FER), which is an indicator of plant vigour (the more vigorous is the growth of the banana trees, the faster is disease development). The Stage of Evolution of the Disease is calculated as SED = SC x FER. SED is an indicator of the potential of development of the disease and timing of decisions is made according to the curve of SED (figure 3).

Figure 3. Evolution of BLSD in a banana plantation of Cameroon, in 1990. In this plantation, timing of fungicide treatments has been decided according to the Stage of Evolution of the Disease (SED). Fungicide applications are represented by arrows: antimitotics (grey, dot-line) and triazoles (black).



1.2. Timing of applications

The time between decision and execution of one application should be as short as possible. Treatments are made by airplane allowing a fast operation. However the climatic conditions required for aerial spraying are limiting, and only a small window, early on the morning and late in the afternoon, is suitable otherwise thermal inversion and air turbulence do not allow correct spray deposition. Aerial application is not possible on rainy and windy days. The logistics available for aerial sprayings are then essential to optimize spraying during this small window.

1.3. Treatment efficacy

The efficacy of treatments is depending on the quality of the foliar application and a good coverage is indispensable. Bad weather conditions on the day of application, an irregular topography or the presence of obstacles might alter its uniformity. The use of mineral oils as carrier considerably improves the quality of coverage through aerial spraying with low volumes (12-15 l/ha). The recent development of GPS for aerial spraying has also enabled a strong improvement in the quality of aerial spraying.

The efficacy of treatments relies also on a strong curative effect and systemic fungicides are thus preferred to contact or penetrant fungicides. The systemic fungicides used for BLSD control where in the beginning antimitotics and triazoles. The strobilurins developed at the end of 90s were still not available when the forecasting system has been developed in Cameroon. Moreover, the use of systemic fungicides in pure oil strengthens their curative effect, because mineral oils have also a fungistatic effect.

Keeping the sources of inoculum at a very low level is also important to ensure good efficacy of treatments. Where extensive spotting is present, new infections will develop quickly because chemical sprays do not eliminate the disease from spotted leaves and the only solution is to remove them mechanically from the banana tree. So, continuous deleafing is done weekly in the banana farms in order to remove spotted material.

1.4. Organization of control

Since ascospores are transported by wind over long distances, the control strategy should be the same in all banana plantations to prevent any disruption. The organization is more efficient if centralized by the same technical service operating according to rational guidelines rather than if each grower implements his own strategy often with short-term objectives. Centralization of decisions and operations are then essential. In Cameroon bananas are grown only by 3 companies (Cie Fruitière, 3000 ha; CDC/Del Monte, 2000 ha; SPM, 800 ha since 1999) which helps in the centralization of BLSD control.

2. Development of fungicide resistance and evolution to a systematic strategy

From 1984 to 1991 this forecasting strategy has performed well with only 12 to 14 applications per year (figure 2). During this period 5-8 and 4-7 treatments/year were realized respectively with triazoles and benzimidazoles, the later being used mainly during the dry season. The forecasting system was managed by a same technical service under the responsibility of the CRBP (Centre de Recherche sur les Bananiers et Plantains, Cameroon, now CARBAP).

After that period, the banana companies decided to manage themselves the forecasting system. Nevertheless bad choices in the logistics for aerial spraying led to a loss of control, and the number of treatments increased in order to go back to a better control. During that period 12 treatments/year with triazoles and more than 10 treatments/year with benzimidazoles were done. This intensive use of systemic fungicides provoked an outbreak of fungicide resistance which could be detected in the monitoring programs for first time in 1996. The fungicide resistance resulted in the progressive abandon of the rational forecasting strategy at the expense of a systematic control strategy. This evolution has also been accompanied by changes in the use of fungicides. Antimitotics and triazoles have been less used, and the proportion of penetrant and contact fungicides has increased. By another hand, strobilurins have been introduced in the spray programs in 1998, but their use has led to a fast development of resistant strains and they were abandoned in 2004. Thus in 2005, about 40-50 treatments were done on most of the plantations and the control program was based on the ratio of 90% of contact fungicides and 10% of systemic and penetrant fungicides (figure 2). This evolution has led to an important increase of the cost of disease control, but also to an increase of negative environmental effects. In fact, the number of treatments has increased by 4, but at the same time, the quantity of active ingredients used/ha has also increased by 10 (systemic fungicides are ordinary used at the rate of 100 g/ha, since contact fungicides are used at rates ranging from 700 to 1500 g/ha). So, these changes resulted in an increase of an amount of active ingredients/ha by 40.

III. DEVELOPMENT OF MORE SUSTAINABLE CONTROL STRATEGIES

Strategies with so much negative environmental effects are not sustainable. In order to develop more sustainable strategies, interest has been pushed on :

(1) experiment fungicides having less negative environmental effects;

(2) adapt control strategies to the situation of fungicide resistance;

(3) evaluate the possible reversibility of fungicide resistance in order to reintroduce a forecasting control strategy using systemic fungicides.

1. Evaluation of bio-fungicides

Various bio-fungicides have been experimented in order to evaluate their effect on BLSD and to identify on what kind of strategy they could be used for the control of this disease. Fungicides having a strong curative effect can be used in a forecasting strategy, since those having a low curative effect require a systematic strategy. These tests have been carried out since 2005, on the experimental station of CARBAP in Nyombe, on banana plots grown with the cultivar Grande Naine, triploïd AAA of sub-group Cavendish, which is highly susceptible to BLSD.

1.1. Biocontrol agents. *Bacillus subtilis* (Serenade) has been tested in different modalities, all of them including oil at the rate of 20l/ha. All treatments with Serenade enabled a significant control of BLSD as compared with an untreated control. Serenade mixed with Dithane F488 at half rates had the same effect than Dithane F488 alone at the full rate. Serenade treatments controlled the disease as well as straight oil and mancozeb mixed in oil. Nevertheless it is not possible to determine whether the efficacy of the Serenade treatments was due to the own effect of *Bacillus subtilis* and/or to the fungistatic effect of oil, since these treatments were mixed in oil.

New experiments started in 2006 in order to evaluate the own activity of Serenade used in water and the interest of mixtures of serenade with mancozeb.

1.2. Essential oils. Timorex, essential oil of *Melaleuca alternifolia,* applied in water did not allow a good control of BLSD. Timorex applied in oil, controlled the disease as well as pyrimethanil, but it is probable that this effect was due to the fungistatic effect of oil. Moreover, Timorex used at this rate was phytotoxic, particularly when used in oil.

1.3. Miscellanous. Alimentary additives, organic acids, and potassium carbonates have been tested in water in a systematic framework of 7 days. None of them controlled BLSD.

1.4. Leachates of decomposted banana and plantain parts. Leachates of decomposted banana and plantain material (bunch stems) have been produced in small units. In a first step, present work aims to evaluate the antifungal activity of such leachates through a biological test on artificial media amended with these leachates. This biological test is either a growth test of *Colletotrichum musae* cultures either a germination test of *Mycospharella fijiensis* ascospores or *Colletotrichum musae* conidia. The antifungal activity of these leachates has been evaluated every week, all along the course of the production process. The stability of the antifungal activity has also been evaluated. The first results are still in progress but show a promising antifungal effect on the two pathogens of some of these leachates of decomposted banana.
In a second step, the ability of such leachates to control BLSD will be evaluated at the field level.

2. Adaptation of systematic strategies

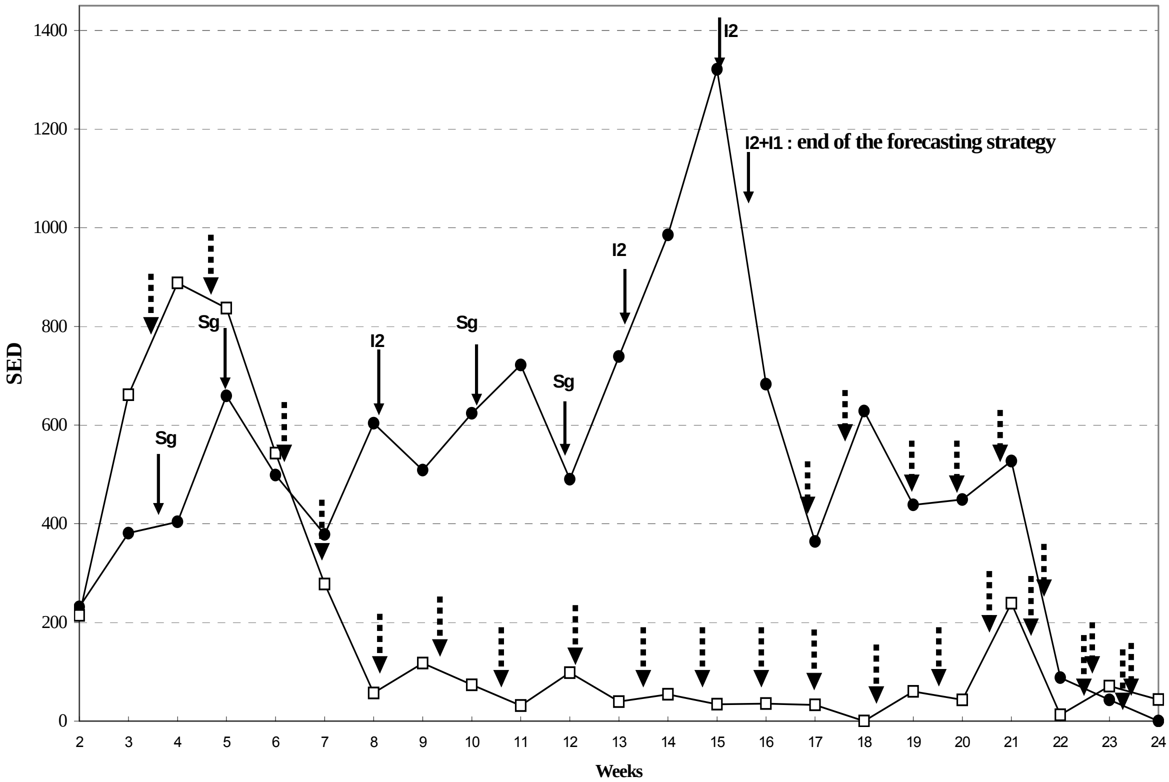
The objective of these trials was to evaluate new strategies excluding the use of systemic fungicides for BLSD control in the commercial banana plantations of Cameroon. Those strategies would then rely on contact (mancozeb, chlorothalonil) or penetrant (pyrimidins, sterol biosynthesis inhibitors of group 2) fungicides. A first experiment was carried out on a commercial banana plantation of 200 ha divided in two equal parts for aerial spraying, in order to compare two different strategies in the dry season and in the rainy season.

2.1. Dry season strategy. The objective was here to investigate the possibility to control BLSD in the dry season using a forecasting strategy with penetrant fungicides. Two strategies were then compared from January to April 2005:

- a strategy where fungicide applications were decided according to the level of the SED. The fungicides used in this strategy were either sterol biosynthesis inhibitors of group 2 (SBI2), either pyrimethanil. SBI2 were applied in straight oil (15 l/ha), and pyrimethanil was used in an emulsion of 7L oil + 8L water + emulsifier.
- a strategy where chlorothalonil (Bravo 720) was used systematically on a 7 day timetable. Bravo was applied in 20L of water/ha.

The systematic strategy with chlorothalonil induced a fast decrease of the SED (figure 4). The SED in the forecasting strategy never decreased significantly and control of the disease was ineffective by the end of the dry season. The end of this strategy was then decided, and an application of Sico + SBI2 enabled a fast decrease of the SED. A conversion of the forecasting strategy to a systematic use of chlorothalonil prolonged the decrease of the SED and enabled an improvement of the sanitary level (figure 4).

Figure 4. Evolution of the SED in the course of an experiment where a forecasting strategy with penetrants (●) has been compared with a systematic use of chlorothalonil (□), during the dry season. Fungicide application are represented by arrows: Siganex (Sg); Sterol Biosynthesis Inhibitors of group 2 (I2); Sterol Biosynthesis Inhibitors of group 1 (I1); Chlorothalonil (dot line).

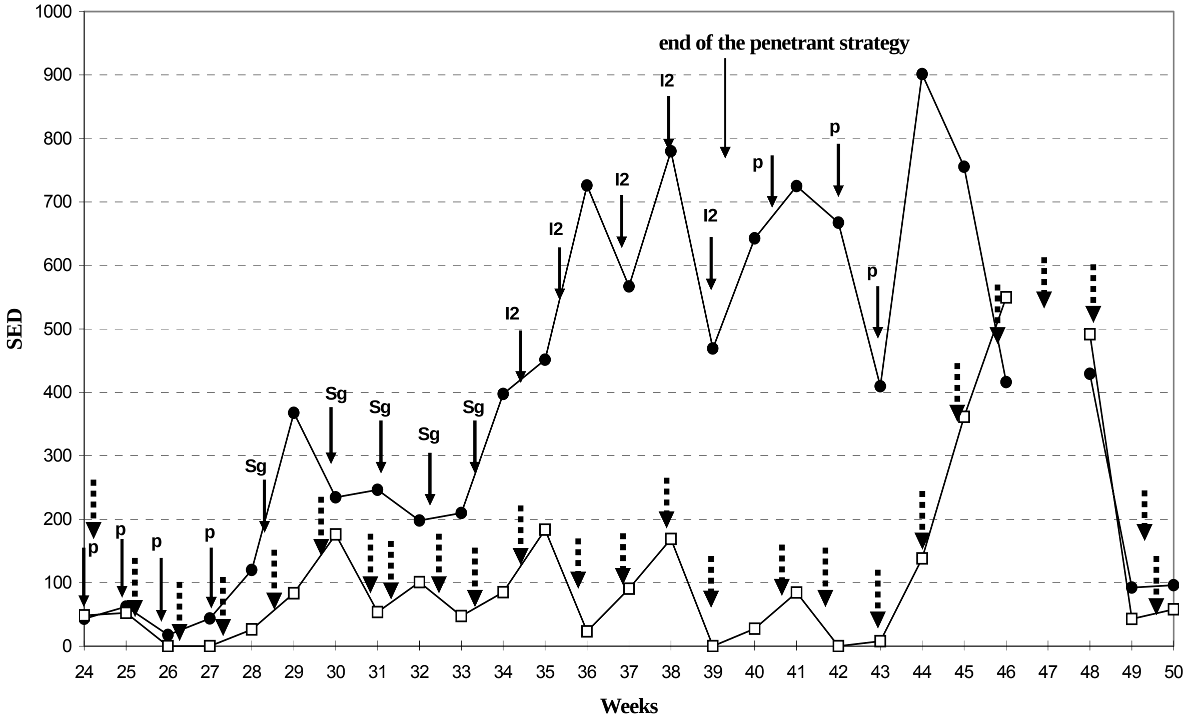


2.2. Rainy season strategies. The objective was here to evaluate the possibility to control BLSD in the rainy season using penetrant and contact fungicides in a systematic strategy. Two strategies were compared from June to December 2005:

- a strategy where penetrants were used systematically on a 10 days timetable. The fungicides used in this strategy were either sterol biosynthesis inhibitors of group 2, either pyrimethanil. SBI2 were applied in straight oil (15 l/ha), and pyrimethanil was used in an emulsion of 7L oil + 8L water + emulsifier.
- a strategy where chlorothalonil (Bravo 720) was used systematically on a 7 day timetable. Bravo was applied in 20L of water/ha.

The systematic strategy with chlorothalonil provided a better control of BLSD in the rainy season than the systematic strategy with penetrants (figure 5). It was decided to stop the penetrant strategy at the beginning of October and, after a transition period of three mancozeb applications in water, to apply a chlorothalonil strategy. Even in the rainy season, the conversion to a chlorothalonil strategy enabled a decrease of the SED and an improvement of the sanitary level.

Figure 5. Evolution of the SED in the course of an experiment where a systematic use of penetrants (●) has been compared with a systematic use of chlorothalonil (□), during the rainy season. Fungicide application are represented by arrows: Siganex (Sg); Sterol Biosynthesis Inhibitors of group 2 (I2); Penncozeb (p); Chlorothalonil (dot line). Penetrants have been applied on a 10 day timetable and chlorothalonil on a 7 days timetable



2.3. Towards a strategy of rational use of chlorothalonil. A new strategy is now experimented in order to rationalize the use of chlorothalonil in systematic strategies relying on contact fungicides. This strategy is presently evaluated over two commercial plantations. In such strategy, chlorothalonil is used until a low disease level is achieved in the plantation (low SED, no leaf spotting i.e; YLS > 12). Then, another contact fungicide (mancozeb) is applied in water until an increase of SED is observed in the plantation; a new conversion to a chlorothalonil strategy is then applied.

3. Evaluation of a possible reversion of fungicide resistance

Regular monitoring of fungicide resistance in the commercial banana plantations has been conducted since 1985 in order to evaluate the sensitivity to systemic fungicides in *M. fijiensis* populations. The methodology used was a germination test of ascospores projected on an agar medium amended or not with a specific fungicide concentration.

Leaf samples were collected in commercial banana plantations as well as in untreated plantations located in the same area (small plantain plots).

3.1. Evaluation of resistance to antimitotics. Sensitivity to benomyl or methyl-thiophanate was evaluated at the concentration of 5 ppm. Those having a distorted germ tube or that did not germinate were considered as susceptible and those with normal germ tubes were considered as resistant. The proportion of resistant strains was then calculated.

The first resistant strains were detected in 1996 in the commercial banana plantations that is after about 10 years of usage. The frequency of resistant strains was heterogeneous in the first years and became progressively generalised (table 2). This spread of resistance to antimitotics has been observed similarly in all commercial banana plantations. Resistant strains were never observed in untreated plantations. In the last monitoring date, there was a trend to a slight decrease of the proportion of resistant strains.

Table 2. Evolution of fungicide resistance to benomyl or methyl-thiophanate (Benlate or Callis) in a commercial banana plantation of Cameroon.

Years	% Resistant strains in the commercial plantations (Min-Max)	% Resistant strains in the untreated plantation
1993	0	0
1994	0	0
1995	0	0
1996	15 (0-60)	0
juil-97	12 (0-60)	0
déc-97	18 (0-55)	0
avr-98	36 (0-80)	0
oct-00	25 (0-51)	0
sept-02	51 (14-82)	0
avr-03	40 (0-64)	0
oct-03	44 (18-60)	0
avr-04	48	0
dec-04	20 (0-48)	0

By another hand, resistance to antimitotics has been detected in two years at high levels (>50% resistant strains) in a new farm created in 2000 where these fungicides had never been used. This farm has been created in Mbanga which is far-off the other commercial farms located in Njombe and Penja. It is then more probable that resistant strains have been introduced through the vitro-plants which were grown in nurseries located in commercial farms of Penja. Specific attention should then be paid to nurseries localization and BLSD control in the nurseries.

3.2. Evaluation of resistance to Sterol biosynthesis inhibitors of group 1. Sensitivity to propiconazole was evaluated at the concentration of 0.1 ppm, and the germ tube length of 50 ascospores was measured with a micrometer on control (Lc) and fungicide amended medium (Lf). The growth inhibition (G.I.) was calculated as: G.I. = $[1-(Lf/Lc)]\times 100$, and the proportion of ascospores in different inhibition classes was also determined. Particularly, the percentage of ascospores falling in the classes represented in the untreated area population (high inhibition classes: GI > 50%) was calculated.
In the commercial banana plantations, the mean growth inhibition (GI) was always inferior to the GI measured in the untreated plantations (table 3). By the same, 100 % of the ascospores from the untreated plantation had a GI > 50 %, which was not the case in the commercial plantations where 10-80 % of ascospores had a GI < 50%. So, after some ten years of usage, some sensitivity shifts to propiconazole were observed in the commercial banana plantations. These shifts were subjected to large variations (the mean GI varied from 30 to 70% and the % of ascospores with GI > 50% varied from 17 to 90%) as illustrated by the variation from October 97 to April 98 and from October 2000 to July 2001.

Table 3. Evolution of fungicide resistance to propiconazole (Tilt) in commercial banana plantations of Cameroon.

Date	Mean GI in the commercial plantation	Mean GI in an untreated plantation	% ascospores with GI > 50% in the commercial plantation	% ascospores with GI > 50% in an untreated plantation
10/1996	61	-	-	-
05/1997	61	-	-	-
10/1997	70	-	-	-
04/1998	54	72	56	-
01/1999	49	-	50	-
01/2000	61	73	80	-
10/2000	61	73	90	100
07/2001	30	78	17	100
01/2002	56	76	60	100
01/2003	49	74	63	100
09/2003	52	72	30	100
05/2004	54	83	52	100
01/2005	61	84	72	100

3.3. Evaluation of resistance to strobilurins

Sensitivity to azoxystrobin was evaluated at the concentration of 1 ppm, and the germ tube length of 50 ascospores was measured with a micrometer on control (Lc) and fungicide amended medium (Lf). The growth inhibition (G.I.) was calculated as: G.I. = [1–(Lf/Lc)]×100, and the proportion of ascospores in different inhibition classes was also determined. Particularly, the percentage of ascospores falling in the classes represented in the untreated area population (high inhibition classes: GI > 70%) was calculated. Azoxystrobin was introduced in spraying programs in 2001.

In the untreated plantation, the mean GI was always > 95 %, and the % of susceptible strains, as expressed as those having a GI > 70 % was always 100 %. In the commercial banana plantations, the use of strobilurins started in 2000 and the appearance of resistant strains was very fast by mid of the year 2004 (table 4). However, after a strong increase in the frequency of resistant strains observed successively in December 2004 and June 2005, there was a trend to an important decrease in November 2005.

Table 4. Evolution of fungicide resistance to azoxystrobine (Bankit) in commercial banana plantations of Cameroon.

Date	Mean GI in the commercial plantation	Mean GI in an untreated plantation	% ascospores with GI > 70% in the commercial plantation	% ascospores with GI > 70% in an untreated plantation
08/2001	90	100	100	100
09/2003	96	98	100	100
04/2004	86	95	74	100
10/2004	34	98	2	100
06/2005	41	97	23	100
11/2005	81	96	73	100

IV. CONCLUSIONS - PROSPECTS

The bio-fungicides that have been experimented have a moderate curative effect because their efficacy would be, in the better case, comparable with that of straight oil or pyrimethanil. This moderate curative effect is not compatible with their use in a forecasting strategy. Nevertheless in a systematic strategy they could be useful in order to reduce the negative environmental effects of BLSD control where systematic strategies are applied. Further work is then needed to determine whether bio-fungicides could be used in water alone in a systematic strategy. As suggested by our results with Serenade, bio-fungicides could also probably be used mixed with contact fungicides at half rates. This perspective could be interesting in order to reduce the amount of active ingredient of fungicide per ha and per year.

The experiments on strategies illustrate the importance of a high curative effect of fungicides for the success of a forecasting control strategy (de Lapeyre de Bellaire *et al*., 2000). A forecasting strategy with penetrants has not proved to be efficient for BLSD control, even during the dry season. It is of interest to note that a systematic strategy with chlorothalonil enabled a perfect control of the disease, even during the rainy season. Further work is in progress to establish a systematic strategy where no systemic fungicide would be applied and where chlorothalonil would be used rationally. In those strategies (i) fungicides would be applied in water alone in order to enable a rapid conversion to chlorothalonil since this fungicide is very phytotoxic in oil; (2) bio-fungicides could be very useful to reduce the environmental pressure. It is hoped that after some years these new strategies could enable to re-introduce systemic fungicides and the use of a rational control strategy based on a forecasting system.

Nevertheless, it will be possible to reintroduce the forecasting strategy only if the fungicide resistance is reversible and/or new systemic fungicides come on the market. Since fluctuations in the levels of fungicide resistance are regularly observed in the regular monitoring tests realized in the commercial banana plantations, there is some hope that a decrease in resistance levels could be observed after a free-use period. The hypothesis put forward is that the fluctuations in the frequency of fungicide resistance could result from a lower fitness of resistant strains, which could be counter-selected in the absence of fungicide treatments, and/or gene flow between the treated and the untreated zones. A better knowledge of the parameters implied in fungicide resistance dissemination inside *M. fijiensis* populations (mutation, recombination, genetic drift, gene flow, selection pressure, population size, competition, fitness) is needed.

Then, future work will focus on:

- Gene flow and dispersion of resistance between plantations. Particular attention will be paid to gene-flow between untreated and untreated plantations.
- Measuring the selection or counter – selection through the usage or non-usage of systemic fungicide.
- Evaluation of fitness of susceptible and resistant strains in artificial inoculations.

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