French Cooperation in Grenada

Report Mission 'Black Leaf Streak Disease control': 28th June to 4th July 2007

L. de Lapeyre de Bellaire

- **Schedule of the mission :**

28th June 2007

- Arrival at Grenada Airport - 15h00pm flight LIAT (delayed)
- Taxi to Hotel GEM
- Telephone contact with Mr Malachy Dottin MOA

29th June 2007

- MOA: meeting with Thaddeus Peters and Everest Ferguson on BLSD control in Grenada. Collection on information data in the MOA.
- Visit of the laboratory of MOA

2nd July 2007

- Visit at Grand Etang (Claudius Pierre's farm)
- Visit at St Cyr (Telphen Noel's farm)
- Visit at Maribeau docks of the MOA
- Visit at Windsor ((Leroy Alexander's farm)
- Visit Belvidere (Samuel Noel's farm)

3rd July 2007

- Preparation of a presentation for meeting with BLSD control staff of MOA
- MOA : meeting with BLSD control staff

4th July

- 6:00 am Departure to Martinique Arrival 9:00 am Flight LIAT

Specific objectives of this mission

The objective of this mission was to review the current strategy being implemented by the MOA for the control of Black Sigatoka, and examine how this strategy could be improved to increase the efficacy of BLSD control in Grenada.

I. Review of Black Sigatoka Disease control practices in Grenada

BLSD has been reported for first time in Grenada in November 2005, one year after hurricane Ivan has hardly damaged all the banana industry of this country. Since that time, no bananas are exported to the UK, the main production being sold on the local market and a small amount being exported to Trinidad. 70-80 growers are growing bananas and considered by the MOA for BLSD control. The quality of BLSD control in Grenada should be considered under this aspect since the requirements for BLSD control on a local market are much more less restrictive than on an export market.

1. Description of Black Sigatoka and its control

This part of the document should be regarded as the background that we have on this disease and possible connections with the situation that we have observed in Grenada.

1.1. The disease and its pathogen

Black Sigatoka or Black leaf streak disease (BLSD) is one of the main parasitic constraints in agro–industrial plantations of dessert bananas. BLSD has been described for the first time in 1963 in Fidji. *Mycosphaerella fijiensis* (anamorph: *Paracercospora fijiensis*) the causal agent of BLSD has progressively spread to most banana growing areas replacing *Mycosphaerella musicola* (anamorph: *Pseudocercospora musae*) causal agent of Sigatoka disease of bananas (SD). BLSD was reported for the first time in Grenada in November 2005.

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. On susceptible varieties of bananas, BLSD provokes the appearance of leaf necrosis, and the attack of the pathogen 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. So, intensive **cultivation of dessert banana for exportation can only be achieved through a perfect control of BLSD**.

1.2. Epidemiology of BLSD

a. Contamination

The contamination includes the pollution of leaves by the spores, their germination, and penetration of the pathogen into the host's tissues. Banana leaves are contaminated either by conidia or by ascospores of *M. fijiensis*. Germination occurs within 2-3 hours on a moist surface, and an epiphyllic growth during 2-4 days is necessary before stomatal penetration of infection hyphae. Germination and stomatal penetration are affected by humidity (the presence of water on leaves is particularly important) and temperature (the optimum temperature is 27°C). Germination and stomatal penetration are also affected by fungal antagonism occurring on old leaves. Thus, stomatal penetration mostly occurs on the youngest leaves: the unfurled leaf (cigar) or the leaf N.1.

b. Incubation period and symptom evolution

The incubation period is the time between stomatal penetration and the first symptom of the disease. The incubation period is very variable according to climatic conditions (humidity and temperature), infection density, plant vigour, and ranges from 10 days in ideal conditions but can be delayed to more than 30 days under unfavourable (dry) conditions.

The transition period refers to the evolution of the disease from stage 1 (minute yellow point) to stage 6 (necrotic grey spot), according to Fouré's scale:

Stage 1: A spot is just visible to naked eye as a minute yellowish speck inferior to 1 mm only on the underside of the leaf.

Stage 2: Red or brown streaks (rust coloured) are visible firstly on the underside of the leaf, then on both sides. These streaks become progressively brown on the underside and black on the upper-side of the leaf. The first outward sign of this stage 2 on the upper-side of the leaf is a yellow streak which becomes progressively brown.

Stage 3: Widening and extension of the stage 2. Conidia can be produced since this stage.

Stage 4: This is the spot stage. The spot takes a circular or elliptical form.

Stage 5: This corresponds to the first of the two necrotic stages: a yellow halo firstly surrounds a black spot

Stage 6: This corresponds to the second necrotic stages, drying out of the centre of the spot is observed, spots take progressively a grey colour, but keep a black halo also yellow surrounded. Ascospores are produced at this stage of the disease.

The duration of this period ranges from 7 to 30 days according to climatic conditions and infection density. When infection is very dense, the coalescence of young stages (2-3) results in very rapid spotting.

c. Sporulation and spore release

Conidia are produced on spots at stage 3-5 and are disseminated over short distances by rain. Ascospores are produced on stage 6 lesions and are disseminated over long distances by wind. Sporulation and spore release depend on the climatic conditions. Perithecia discharge occurs when drying after previous wetting. Since *M. fijiensis* is heterothallic, the density of perithecia depends on the density of the infection.

d. Consequences for control strategies

As a consequence of antagonism on old leaves, infection mostly occurs on the cigar or leaf N.1.**Thus, new attacks should be detected on young leaves** because if the climatic conditions are very favourable to the development of the disease, the first symptom could be observed after 12-15 days on the leaf N.2, considering that the Foliar Emission Rate (FER) is one leaf/week. If the climatic conditions are less favourable, the first symptom will be observed on either leaf N.3 or on older leaves, or not at all. **There is a gradient of evolution of the disease from the top to the bottom of the banana tree**, and fungicide applications should be aimed at the top of banana trees to control new infections.

The incubation period, as well as the transition period is very variable according to climatic variations. This indicates a **real possibility for forecasting systems to work where climatic conditions might be unfavourable to disease** development (dry conditions).

In order to control field inoculum, it is essential to control the disease before necrotic formation as sporulation starts in stages 3 and 4. **Where leaves are heavily spotted they should be removed since they might produce ascospores for many months**. By another hand, contact fungicides are not curative, so they are effective only before the penetration of the fungus and are useless in all forecasting strategies that rely on symptom observations. Systemic fungicides have a curative effect on streaks (stages 1, 2, 3), but not on necrotic lesions (stages 5, 6), even if sporulation is temporary decreased. For efficient control of the disease, it is important therefore to avoid necrotic formation.

As wind-transported ascospores can disseminate the disease over long distances, **control of the disease should be maintained by all growers of the area, using the same technical guidelines**. Failure of control in one area can affect neighbouring areas.

e. Generalities on BLSD 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. In some countries, forecasting systems have been established and treatments are decided as a function of the Stage of Evolution of the Disease (French West Indies, Cameroon, Ivory Coast). Three types of fungicides are used: (i) contact fungicides which have only a preventive effect (dithiocarbamates, chlorothalonil), (ii) penetrant fungicides (Sterol biosynthesis inhibitors of group 2 and pyrimethanil) which have a moderate curative effect and (iii) systemic fungicides which have a stronger curative effect. These are antimitotics (benzimidazoles), Sterol biosynthesis inhibitors of group 1 (triazoles) and respiratory inhibitors (Qo inhibitors or strobilurins). 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. Only systemic fungicides can be used in forecasting systems that rely on a strong curative effect. Finally, in the treatment strategies, fungicides are used in alternation or in mixtures. 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 in banana exporting countries.

2. Black Sigatoka control practices in Grenada

2.1. Organisation of the control

Control of BLSD in Grenada is a chemical control through ground spraying of fungicides. Since 2002, the control of the Sigatoka disease and lately of BLSD is managed by the Pest and Management Unit (PMU) of the MOA (Paul Graham, Director) and this service is totally free for growers.

In the PMU, the Coordination of the Banana Pests and Diseases unit is made by Thaddeus Peters, and Everest Ferguson is in charge more especially of the Black Sigatoka Disease team. This unit comprises two Field teams in charge of ground spraying (Team 1: Roy Swan, leader, Gabriel Ogilvie, Denis Charles, Nalton Lessy, Augustine Noel, sprayers; and Team 2: Steven Cox, leader, Anthony Francis, Wayne Greenidge, Kenny Smith, Spencer Telesford, sprayers) and a Disease monitoring team (Evon Alexander, Michael Williams).

Spray programs are decided by T. Peters and E. Ferguson. Their decisions are transmitted to the Field team units.

The atomizers are loaded with a charge of 12 l and this charge allows the coverage of 2 acres (0,8 ha). The amount of oil/ha is then of 15 l/ha.

The fungicides are all systemic fungicides: they penetrate inside the leaf tissue and can be redistributed at a more or less important distance from the point of penetration. They have a curative effect and can be used in a forecasting program based on symptoms observation. They have a uni-site or oligo-site mode of action on the fungal biology. Three groups of systemic fungicides are distinguished according to their mode of action. The antimitotics (Sigma), the sterol biosynthesis inhibitors of group 1 (Tilt), and the strobilurins (Bankit). The resistance risk to this class of fungicides is considered as important and particularly important for two of them, the antimitotics and the strobilurins.

Table 1: Fungicides used in Grenada

Fungicide, commercial product (c.p.)	**Tilt 250 EC**	**Bankit 250 SC**	**Sigma 40 OS**
active ingredient (a.i.)	propiconazole	azoxystrobin	methyl-thiophanate
chemical group	triazole	strobilurin	benzimidazole
mode of action	sterol biosyntesis inhibitor group 1	Qo inhibitor	antimitotic
concentration (a.i.) in commercial product	250 g/l	250 g/l	400 g/l
miscibility in oil	yes	adjuvant needed	yes
recommended rate (a.i./ha)	100 g/ha	100 g/ha	320 g/ha
recommended rate (c.p./ha)	400 ml/ha	400 ml/ha	800 ml/ha
recommended rate * (c.p./charge)	320 ml/charge	320 ml/charge	640 ml/charge
rate used in Grenada (a.i./ha)	42-90 g/ha	24-28 g/ha	135 g/ha
rate used in Grenada (c.p./ha)	168-360 ml/ha	94-112 ml/ha	337 ml/ha
rate used in Grenada * (c.p./charge)	135-288 ml/charge	75-90 ml/charge	270 ml/charge

* This rate is for a ratio of 12 l for 2 acres (0,8 ha), i.e. 15 l mixture/ha

a.i. = active ingredient; c.p. = commercial product; the charge is the quantity of mixture loaded in the tank of the atomizer (12 l)

Remarks:

1. The quantity of mixture sprayed/ha (15 l/ha) is probably not sufficient to ensure a good coverage. This rate is sufficient for airplane spraying, but for ground spraying the recommended rate for a correct coverage is more important: 20 l/ha. So, one atomizer charge (12 l) should better allow the coverage of 1,5 acres instead of 2.
2. The fungicides are not used at a proper rate (Table 1):

- The **guideline for rate use is not the same inside all the Sigatoka Team**. For instance Tilt is used at the rate of 135 ml/charge (42 g a.i./ha) for one team to 288 ml/charge (90 g a.i./ha) for the second team, since the recommended dose is 320 ml/charge (100 g a.i./ha). This rate is calculated for a ratio of 1 charge (12 l) for 2 acres.
- **Measurements of rates are not accurate**: (1) the measurement of the quantity of oil is not accurate (no graduation in the tank used for oil) and (2) the quantity of fungicide added to the oil is very empirical. This situation does not guarantee that the right rate is used.
- **Theoric rates are not correct for most fungicides and too low.** For instance, the rate for Bankit is 100 ml c.p./ha instead of 400ml c.p./ha; Sigma : rate is 350 ml c.p./ha instead of 800 ml c.p./ha ; Tilt : rate is sometimes as low as 180 ml c.p./ha instead of 400 ml c.p./ha.

Since rates are too low, the fungicide applications might not be efficient and this situation is favorable to the development of resistant strains.

3. Formulations of fungicides are not properly used:

According to the fungicide formulation, an adjuvant should be added for a correct suspension of the fungicide in the oil. For instance, Bankit SC is not miscible in oil alone and an adjuvant must be added in the mixing process. We could see in the visit in Mirabeau that this is not done and without this adjuvant Bankit does not mix in the oil. This could explain why phytotoxicity occurred previously with Bankit use. More attention should be paid to the formulations used and the strobilurin Tega EC should be preferred to Bankit SC for application in oil

2.4. Fungicide application criteria and disease assessment

Disease assessment is useful in order to take decisions for the application of fungicides and to evaluate the efficiency of the chemical strategy. BLSD is monitored by a team of two persons who assess the following parameters:

- YLS = the youngest leaf with spots. This data is collected on 25 plants and is an indication of the level of leaf spotting.
- NFL = the number of functional leaves: this data is collected just before flowering on 25 plants and is an indication of disease level just before the end of new leaf emission.
- CV = Cronshaw value. This data is evaluated on 10 plants and is a quantification of infection on the younger leaves (leaves 1 to 5).

The spray program is elaborated by the coordinator of the Banana Pests and Diseases unit and the coordinator of the Black Sigatoka team. This spray program cannot be decided according to disease assessment, since these data are too scarce (table 2, Figures 1, 2, 3). By another hand, data collected do not enable a direct connection between fungicide applications and disease control.

Table 2. Number of disease reports realized in reference farms of Grenada in 2006.

Area/grower	**Number of reports /year**
Belvidère/C. Pierre	5
Belvidère/R. Ragbirsingh	5
Clozier/C. Gurley	3

Remarks

1. The **evaluations made by the MOA do not enable a continuous history of BLSD development** in a same place, since these assessments of disease are made at too many large intervals and not on the same plants. It is then not possible to use this information in order to take decisions.

2. The **evaluations made by the MOA do not enable the connexion of the chemical strategy with BLSD development in the farms**.

3. The evaluations made by the MOA do not enable to evaluate the exportability of harvested bunches since no assessment of NFL at harvest is made.

4. The **control of BLSD in commercial banana farms of Grenada has not always been good as** illustrated on the figures 1, 2 and 3. The field visits confirmed that high spotting is present in many farms (especially in St Cyr, Belvidere and Windsor).
In Belvidere plants with bunches at harvest had less than 2 functional leaves.

Fig 1. BLSD monitoring in 2006 in Clozier: C. Gurley

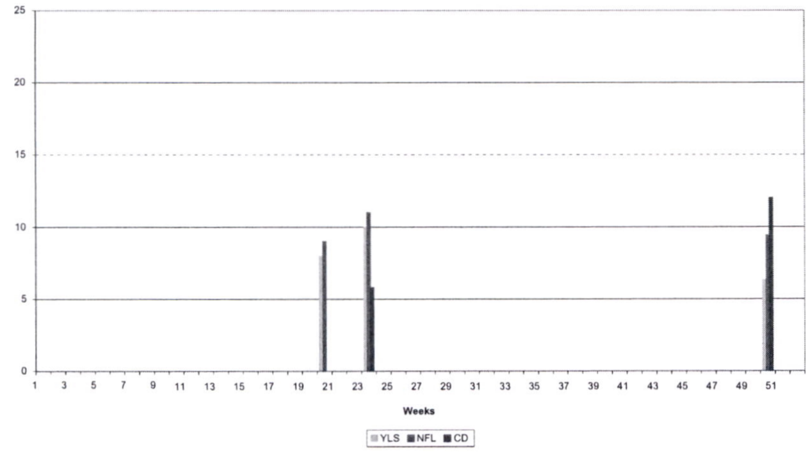


Fig 2. BLSD monitoring in 2006 in Belvidère: R. Ragbirsingh

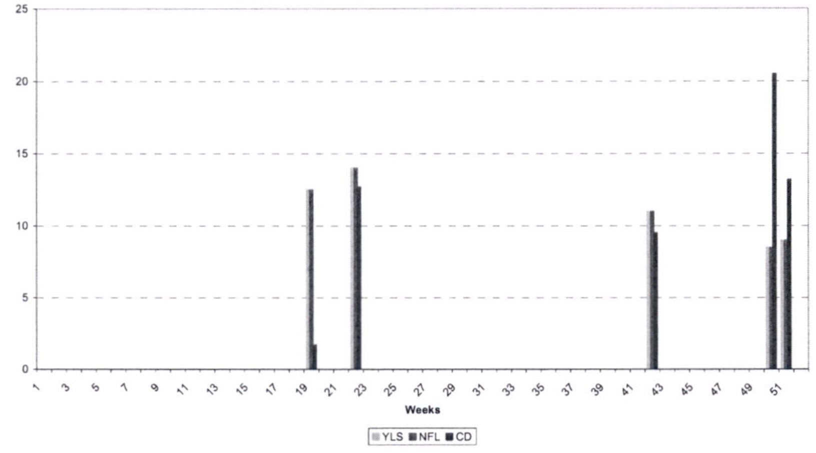
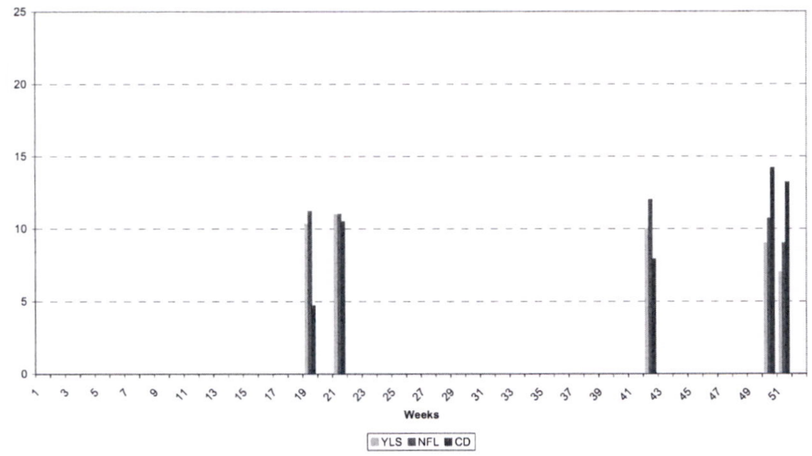


Fig 3. BLSD monitoring in 2006 in Belvidère: C. Pierre



3. History of fungicide use in Grenada

It is particularly important to know the history of fungicide use, especially for the systemic fungicides. This is an important feature for the diagnostic in order to evaluate the risk of fungicide resistance to the chemicals but also to evaluate the chemical strategy used. The general thinking in MOA is that each farm should be treated every month. It has not been possible to find information before 2006, and we have selected reference farms to describe fungicide use since 2006. In reality, the level of fungicide treatments is much lower and 3 to 6 fungicide applications have been realized in 2006 (Tables 3 & 4).

Table 3. Number of treatments realized in reference farms of Grenada in 2006.

Area/grower	Tilt	Sigma	Bankit	Total
Belvidère/C. Pierre	2	2	0	4
Belvidère/R. Ragbirsingh	2	3	0	5
Gd Etang/C. Pierre	2	1	0	3
Clozier/C. Gurley	4	2	0	6
St Cyr/T. Noel	2	2	0	4

Table 4. Number of treatments realized in reference farms of Grenada in 2007 (January-June).

Area/grower	Tilt	Sigma	Bankit	Total
Belvidère/C. Pierre	2	0	1	3
Belvidère/R. Ragbirsingh	1	0	1	2
Gd Etang/C. Pierre	1	0	0	1
Clozier/C. Gurley	2	0	1	3
St Cyr/T. Noel	3	0	1	4

Remarks:

1. Data for fungicide applications are not registered properly (electronic archiving). It is important to register the use of chemicals in order to be able to know the whole history of fungicide use in the different farms and to evaluate better the risk of fungicide resistance.
2. **The use of chemicals in Grenada is not very intensive as compared with other countries.** According to the climatic conditions that prevail in this country (annual rainfall in Belvedere is 2900 mm, which show very favourable conditions), it is not expected that a correct control of this disease (for export standards) could be achieved, especially in the rainy season

4. Fungicide resistance to systemic fungicides in Grenada

In several countries the intensive use of systemic fungicides has resulted in an important development of resistant strains in *Mycosphaerella fijiensis* populations. These data are well documented inside the banana working group of FRAC (Fungicide Resistance Action Committee). The resistance risk is considered as severe for strobilurins and antimitotics, and important for SBI of group 1. No data exist in Grenada, and this knowledge is very important in order to decide if the chemicals used are suitable for disease control in this country. Since *M. fijiensis* is a pathogen recently introduced in this country it is important :

- To determine the baseline sensitivity of the pathogen before fungicide use
- To know whether all the groups of fungicides could be used in Grenada or whether the strains that arrived in this country were aldready resistant to some of these fungicides

II. Possible improvement of BLSD control in Grenada

It is noteworthy that the introduction of BLSD in Grenada is recent and that the level of inoculum is going to increase in the next years. The situation of this disease will then be more serious than it has been until now, and an improvement of control methods should be implemented. These are the different points that could be improved.

1. The chemical strategy

It is very important to ensure that fungicides are used at the correct rate. This is particularly important for a good efficiency of the chemical applications and also for management of fungicide resistance. This would require that:

- The fungicides are recommended at the correct rate by PMU officers (use international standards for BLSD control, table 1)
- Each Sigatoka team is using the fungicides at the correct rates : procedures for preparation of mixtures should be given to each team (data-sheet instructions) ; accurate methods are used for volumetric measurements (oil, fungicides); all the required material for volumetric requirements is available for the 2 Sigatoka teams.
- The quantity of oil /ha that is really used in the different areas is effectively controlled. The standard should be 20 l mixture/ha (1 charge of 12 litres for 1,5 acres).
- Fungicides are correctly used for mixing in oil. For instance Bankit should be used with an adjuvant.
- Commercial formulations compatible with oil should be preferred to other formulations. For instance, for strobilurins, Tega EC should be preferred to Bankit.

2. Disease assessment

In order to evaluate the effect of the chemical control strategy on BLSD, **we propose that BGA adopt the assessment of this disease through the SED.** The SED would be evaluated as in the method described by Fouré. This parameter is an indicator of the dynamics of the disease and is helpful to observe the immediate effect of fungicide applications. In this method, the young attacks of the disease are quantified by scoring the most advanced stage of the disease according to Fouré's scale on the leaves n°2 to 4. A coefficient attributed to all (leaf number)/(stage of the disease) association, enables the calculation of the SED, through the multiplication of the Summ of the Coefficients by the Foliar Emission Rate.

Beside the SED other parameters should be monitored :

- The 'Youngest Leaf Spotted', YLS should be scored according to Stover's method. The value is the position of the youngest leaf bearing necrotic stages of the disease (stages 5 to 6). The weekly evolution of this parameter is helpful to express the efficiency of the fungicide control through the balance between the development of necrotic lesions and the foliar emission rate.
- The 'Youngest Leaf bearing Streaks' (YLSt). This is the position of the youngest leave bearing symptoms of the disease. This parameter reflects the incubation period of the disease under a spraying program.
- The Number of Functional Leaves at Harvest, NLH. A functional leave should have less than 15-20% of necrotic surface. This parameter is not directly linked to the chemical applications. Nevertheless since BLSD effects mainly affect fruit quality, the NLH is the final estimator of how has been working the control strategy, since it is (arbitrarily) considered that the NLH should not be < 4. Bunches harvested on plants with NLH<4 are rejected in the packing station for exportation.

This new information would not replace disease assessments formerly realized by BGA technical agents but would contribute to a better disease management. This information is particularly important in experimental designs and also to evaluate the effect of the chemical strategy.

We also recommend that MOA monitor the disease weekly on some reference points. That means that fewer plantations should be assessed, but that disease assessment would be carried every week on these reference points. This continuous information would be very helpful for timing of fungicide applications and also to observe the effect of the fungicide applications.

3. Management of field inoculum

Keeping the sources of inoculum at a very low level is also very important to ensure the success of the chemical control strategy. Where extensive spotting is present, new infections will develop quickly because chemical sprays do not remove the disease from spotted leaves and the only solution is to remove them mechanically from the banana tree.

Such deleafing is ordinary a regular practice in banana growing countries where BLSD is present. **In Grenada deleafing is not very regular and strong efforts should be done to reinforce the chemical control strategy**. This is particularly important in a situation where fungicide spraying is not very effective. **A strong communication effort should be done towards the farm managers in order to improve the situation**, because no chemical control strategy will be successful if the deleafing is not done proper

4. Use of resistant varieties

Since fungicide control is very difficult in the conditions of Grenada, and since banana production is for a local market, **our main recommendation in order to improve BLSD management would be to introduce resistant varieties** for which fungicide control is not necessary. Since the banana market is a local market, new varieties could probably be used by farmers.

For instance, these varieties could be for dessert bananas : IDN 110, FHIA 01, FHIA 15, FHIA 18, FHIA 23…; for cooking bananas: Pelipita, Fougamou, FHIA 3, and FHIA 21…

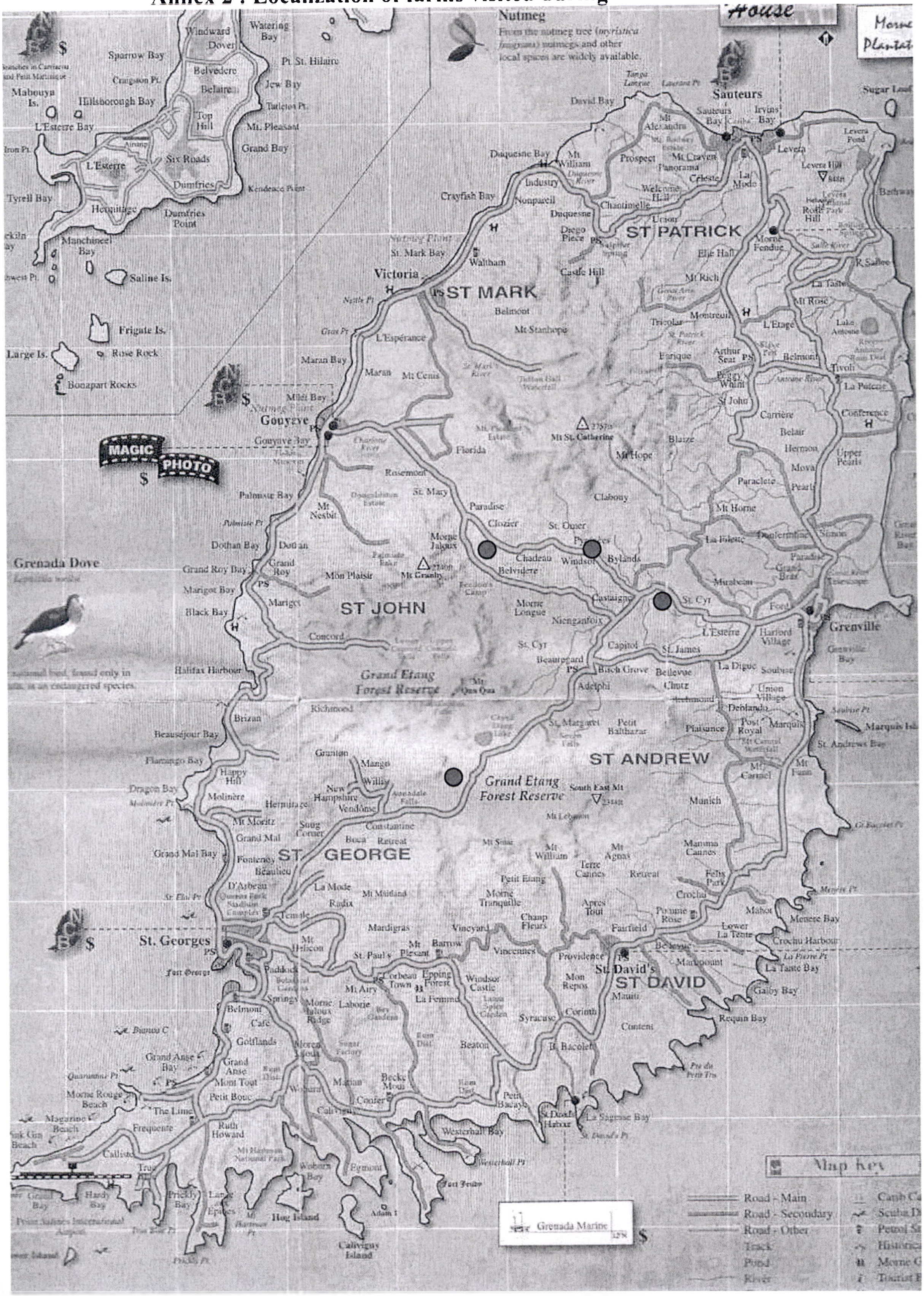
5. Training

We recommend that technical team of MOA would be trained for the new assessment methods of the disease; for the use of a forecasting system; for correct use of fungicides. This training could be done either on Sigatoka disease in Guadeloupe or Martinique, either in Cameroon for BLSD.

Annex 1 - List of persons consulted

Name	Position	Organisation
Thaddeus Peters	Coordinator of Banana Pest Management unit	Ministry of Agriculture
Everest Ferguson	Coordinator of Black Sigatoka unit	Ministry of Agriculture
Michael Williams	BLSD monitoring	Ministry of Agriculture
Roy Swan	Leader of Field team 1	Ministry of Agriculture
Gabriel Ogilvie	Sigatoka Control agent	Ministry of Agriculture
Denis Charles	Sigatoka Control agent	Ministry of Agriculture
Nalton Lessy	Sigatoka Control agent	Ministry of Agriculture
Augustine Noel	Sigatoka Control agent	Ministry of Agriculture
Steven Cox	Leader of Field team 2	Ministry of Agriculture
Paul Graham	Director of Pest Management Unit	Ministry of Agriculture

Annex 2 : Localization of farms visited during this Mission



ANNEX – 3-
Restitution of the mission presented to MOA on July 3rd 2007

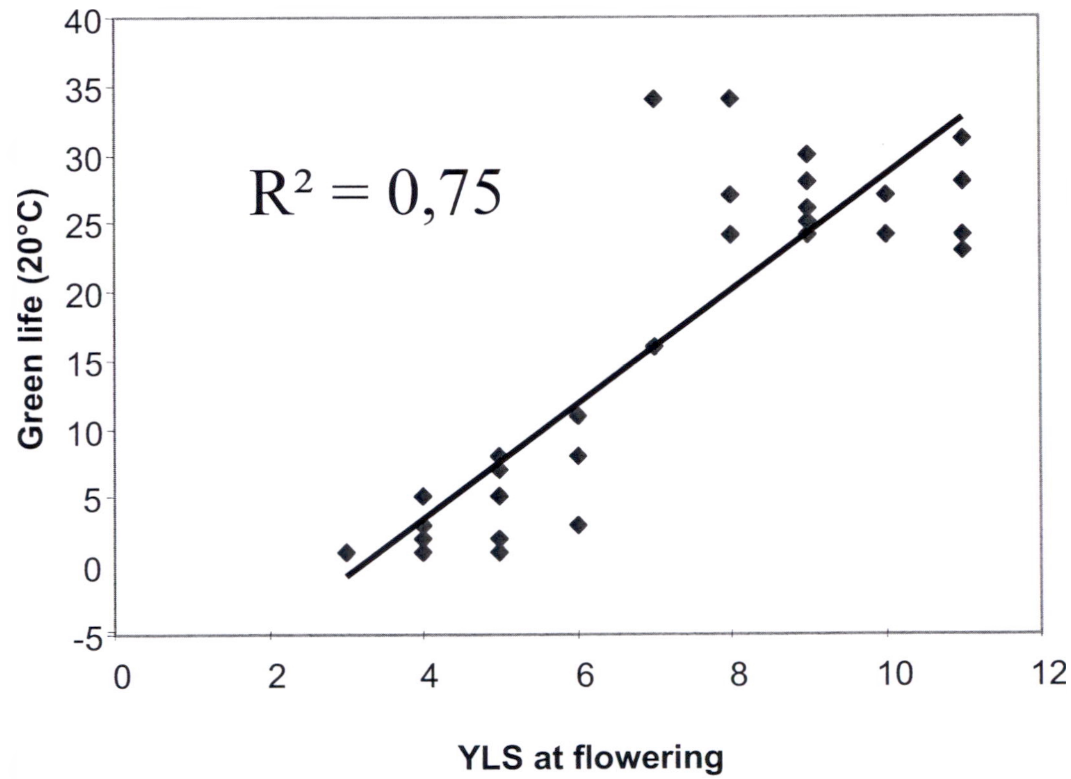
Improvement of Black Leaf Streak Disease Control in Grenada commercial banana plantations

L. de Lapeyre de Bellaire

Generalities on Black Leaf Streak Disease

Effets of BLSD

- Important leaf spot reduces photosynthetic activity … lower yields



- Important reduction in greenlife

CIRAD

Generalities on Black Leaf Streak Disease

<u>High economic Impact</u>

- No resistant varieties for export bananas (all Cavendish)
- Chemical control is the only solution in agro-industrial cropping systems : up to 10 % of production cost (0,5 to 1,5 USD/box)
- important technical constraint (continuous elimination of infected leaves, number of functional leaves at harvest)
- important losses in untreated areas (small growers)

CIRAD

BLSD control in intensive commercial plantations

Main characteristics

1. Type of strategy :
   - Systematic strategy → 7-12 days intervall
   - Forecasting strategy → Timing of decisions according to young infections (SED)
   - Climatic conditions → Dry conditions are good for forecasting
2. Type of fungicide :
   - Contact (no curative effect – no resistance)
   - Penetrant (low curative effect – low resistance risk)
   - Systemic (high curative effect – high resistance risk)
3. Fungicide use :
   - Rotation
   - Mixtures
4. Level of susceptibility to the fungicides

CIRAD

Main fungicides used for BLSD control in the world

1. Contact fungicides :

Only a preventive effect, no curative, used in systematic frameworks

- mancozeb (1000 to 1500 g/ha) in water, emulsion or oil

Various formulations according to the carrier (adjuvants needed in emulsions according to formulations)

Pencozeb, Vondozeb, Dithane WP or DG in water; Dithane, Manzate, Vondozeb SC or OS or OF for oil or emulsions)

- chlorothalonil (720 g to 1000 g/ha) in water

Bravo, Chloroplant, Baléar SC

CIRAD

Main fungicides used for BLSD control in the world

2. Low curative effect fungicides (penetrants or systemics):

Low curative effect especially on BLSD

- Sterol biosynthesis inhibitors group 2: 350 to 450 g/ha

Morpholines : OL or EC formulations can be used in oil or emulsions

Calixin OL (tridemorph): withdrawn from positive list of annex 1/EU

Tern EC (Fenpropidin)

Volley OL (Fenpropimorph)

Spiroketalamines : 350 g/ha EC formulations can be used in oil or emulsions

Impulse EC (spiroxamin)

- Pyrimidins : 350 g/ha SC formulations must be used in emulsions

Siganex SC (pyrimethanil)

CIRAD

Main fungicides used for BLSD control in the world

3. High curative effect fungicides (systemics):

Used in oil or in emulsions - Risk of fungicide resistance

- antimitotics : action on mitosis 125 to 300 g/ha;

Benlate OD (benomyl) withdrawn from positive list of annex 1 of the EU

Callis, Peltis OL (Methyl-thiophanate) : adjuvant needed in oil

Sigma OS (methyl-thiophanate) : no adjuvant needed in oil

-Sterol biosynthesis inhibitors group 1 : action of fungal growth 100g/ha

Tilt (propiconazol) , Sico (difenoconazol), Baycor (bitertanol), Opal (epoxyconazol), Punch (Fluzilasol) EC; Folicur EW (tebuconazole)

- Strobilurins : action on mitochondrial respiration : 100g/ha

Bankit SC (azoxystrobin) : adjuvant needed in oil

Tega EC (trifloxystrobin) : no adjuvant needed in oil

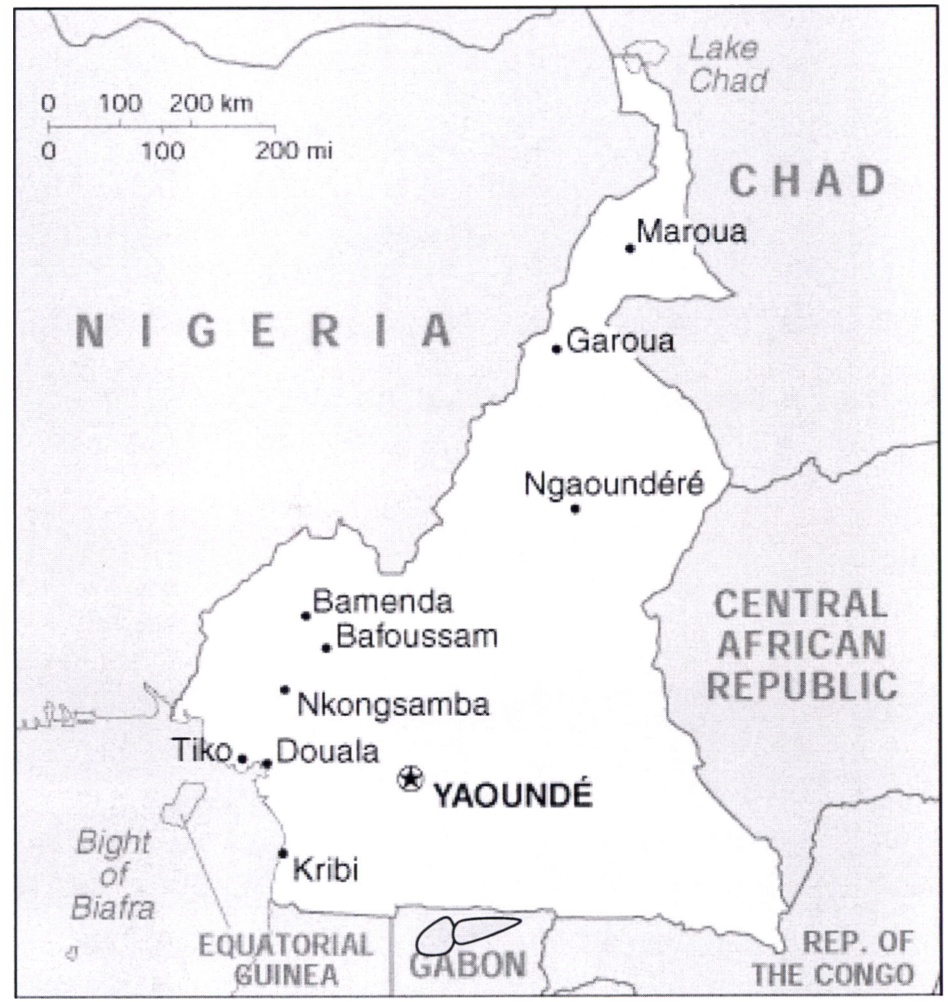
CIRAD

Black Leaf Streak Disease in Cameroon

First report in Africa :
Zambia, 1973

Reported in 1978 in Gabon

First report in Cameroon :
Kribi, 1980

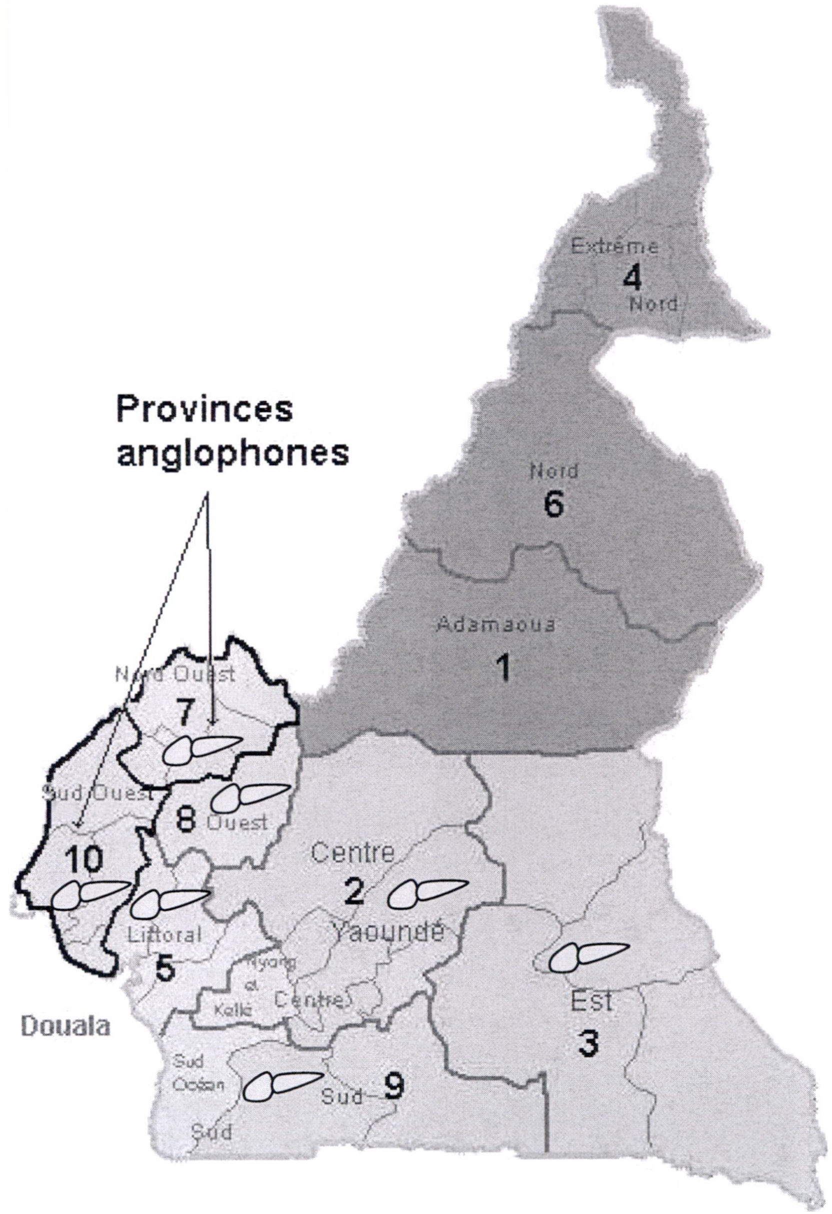


CIRAD

Black Leaf Streak Disease in Cameroon

Progressive Invasion in all provinces :
M. fijiensis replaces *M. musicola* were bananas are grown in humid conditions

New threat for plantain :
Small growers were not prepared
Plantain resistant to *M. musicola*



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Black Leaf Streak Disease in Cameroon

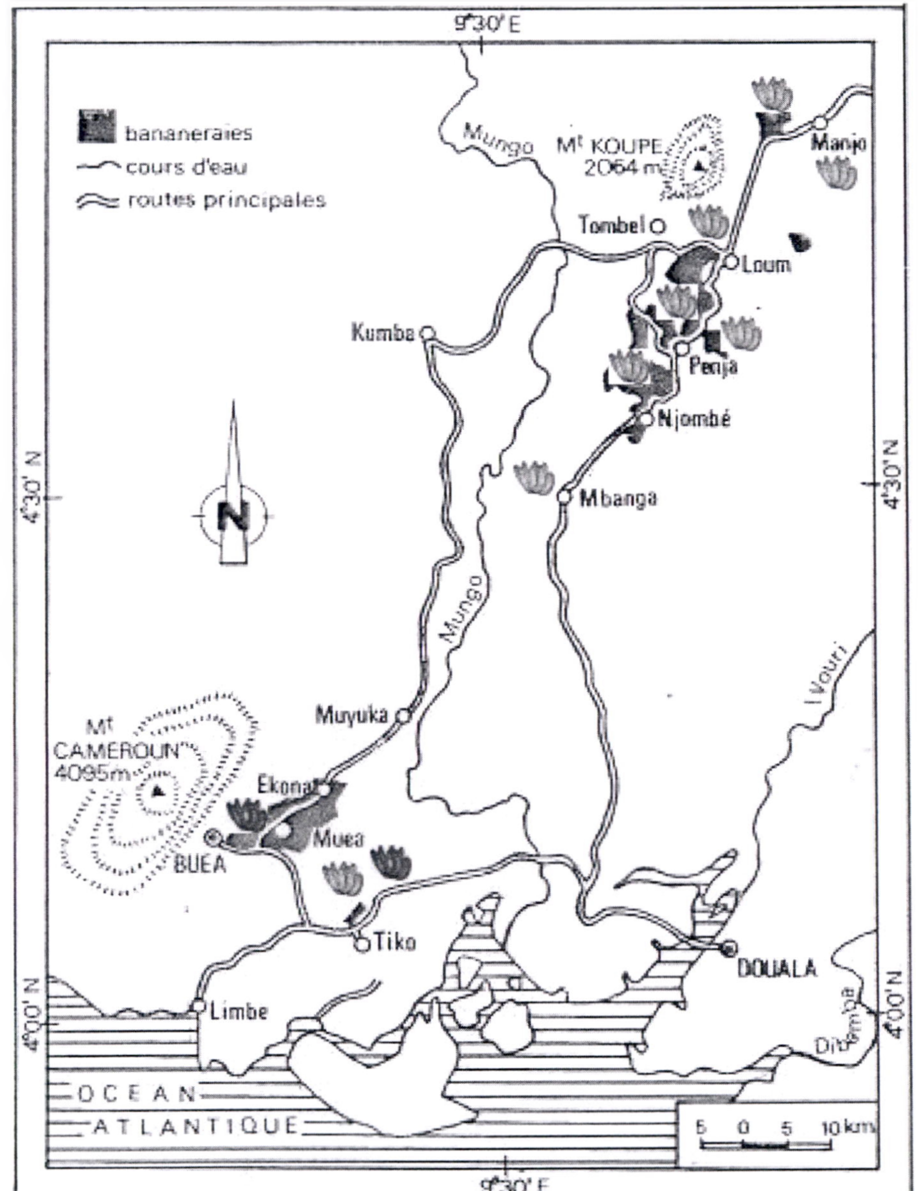
Progressively infested all the banana industry

The banana industry in Cameroon : 3 companies

PHP : 3000 ha

CDC/Del Monte : 2000 ha

SPM : 800 ha



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Diagnostic of BLSD control in Cameroon

Epidemiological conditions

- very favorable conditions for BLSD : climatic conditions, high inoculum
- 'dry' season from November to March

High economic Impact

- up to 10 % of production cost (0,55 USD/box)
- important technical constraint

  - continuous elimination of infected leaves

  - export is depending on the number of functional leaves at harvest (important direct and indirect losses)

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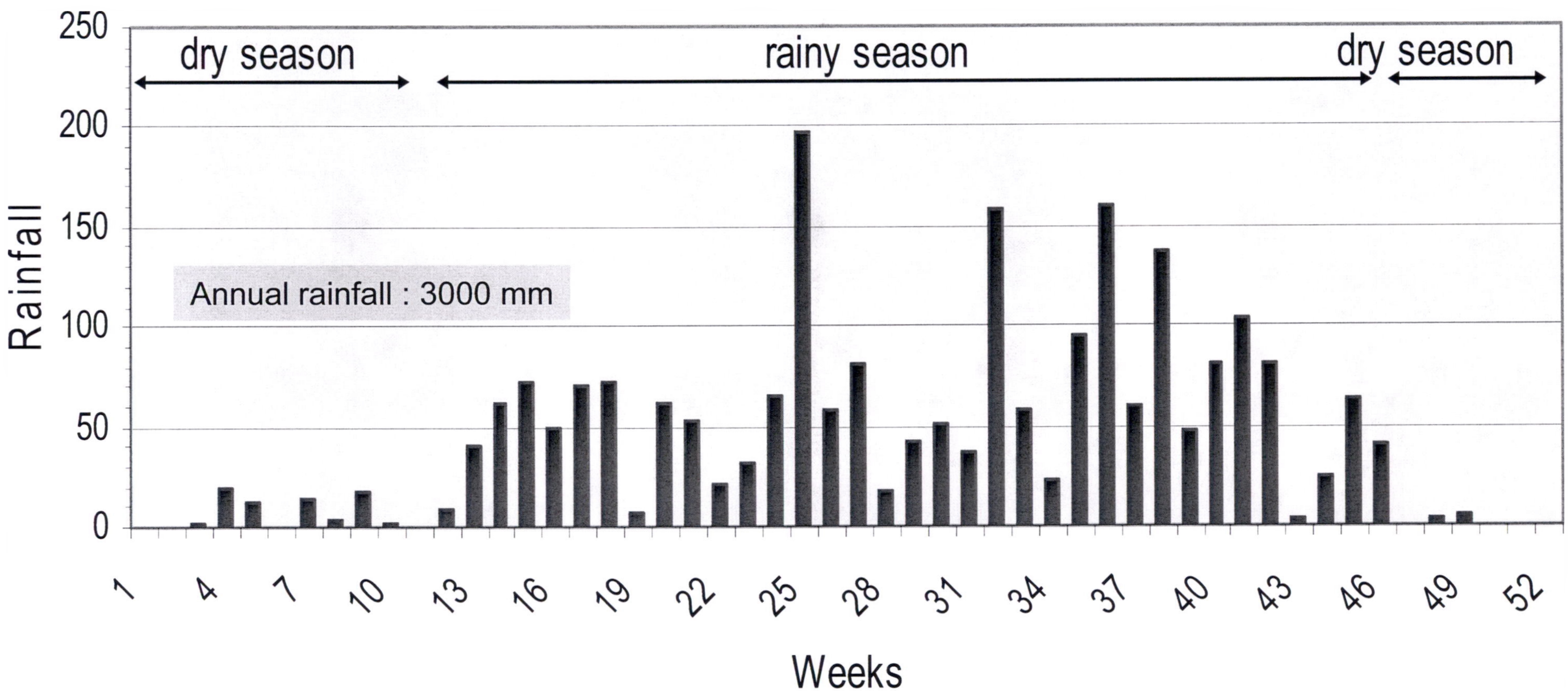
Black Leaf Streak Disease in Cameroon



BLSD control in Cameroon

A forecasting strategy has been designed for BLSD

This strategy was based on :

1. Timing of decisions according to the weekly evaluation of young infections on leaves II, III, IV and the calculation of the Stage of Evolution of the disease (SED)
2. The use of systemic fungicides (antimitotics, IBS1, Strobilurins)
3. The use of oil

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Criteria for BLSD assessment

Functional leaves at harvest
green life – export feasibility

Criteria for BLSD assessment

Continuous information on same plants

Disease -

Stage of evolution : quantification of new infections

Youngest leaf with streaks: incubation

Youngest leaf spotted: efficiency of control strategy

Disease +

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Criteria for BLSD assessment

Weekly observation of same 10 unflowered plants

For a same leaf, the coefficient value increases with the stage of the disease

Stage of the disease		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
	+	220	200	180
5	-	220	200	180
	+	260	240	220
6	-	260	240	220
	+	300	280	260

For a same stage, the coefficient value increases with leaf rank

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

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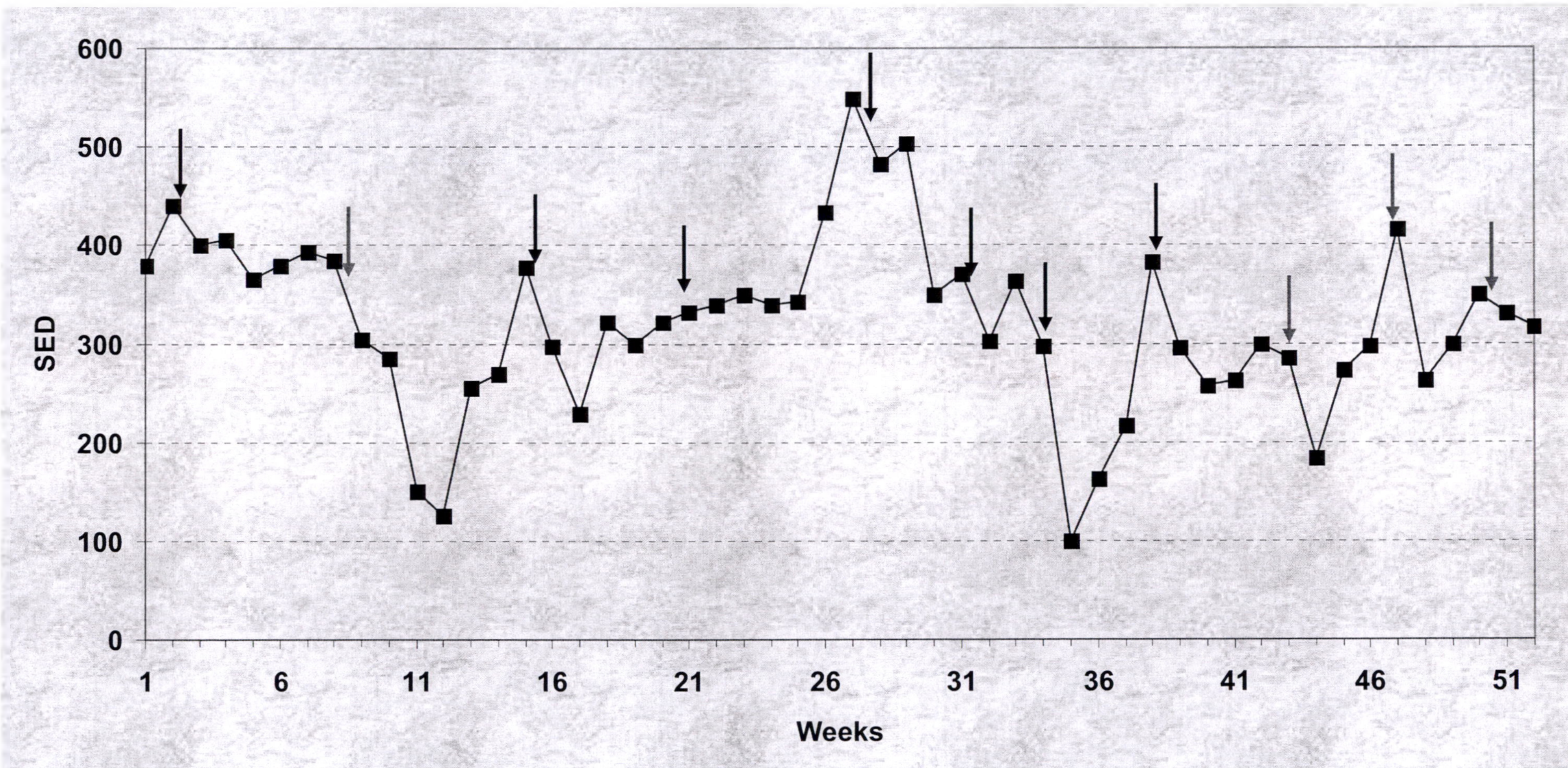
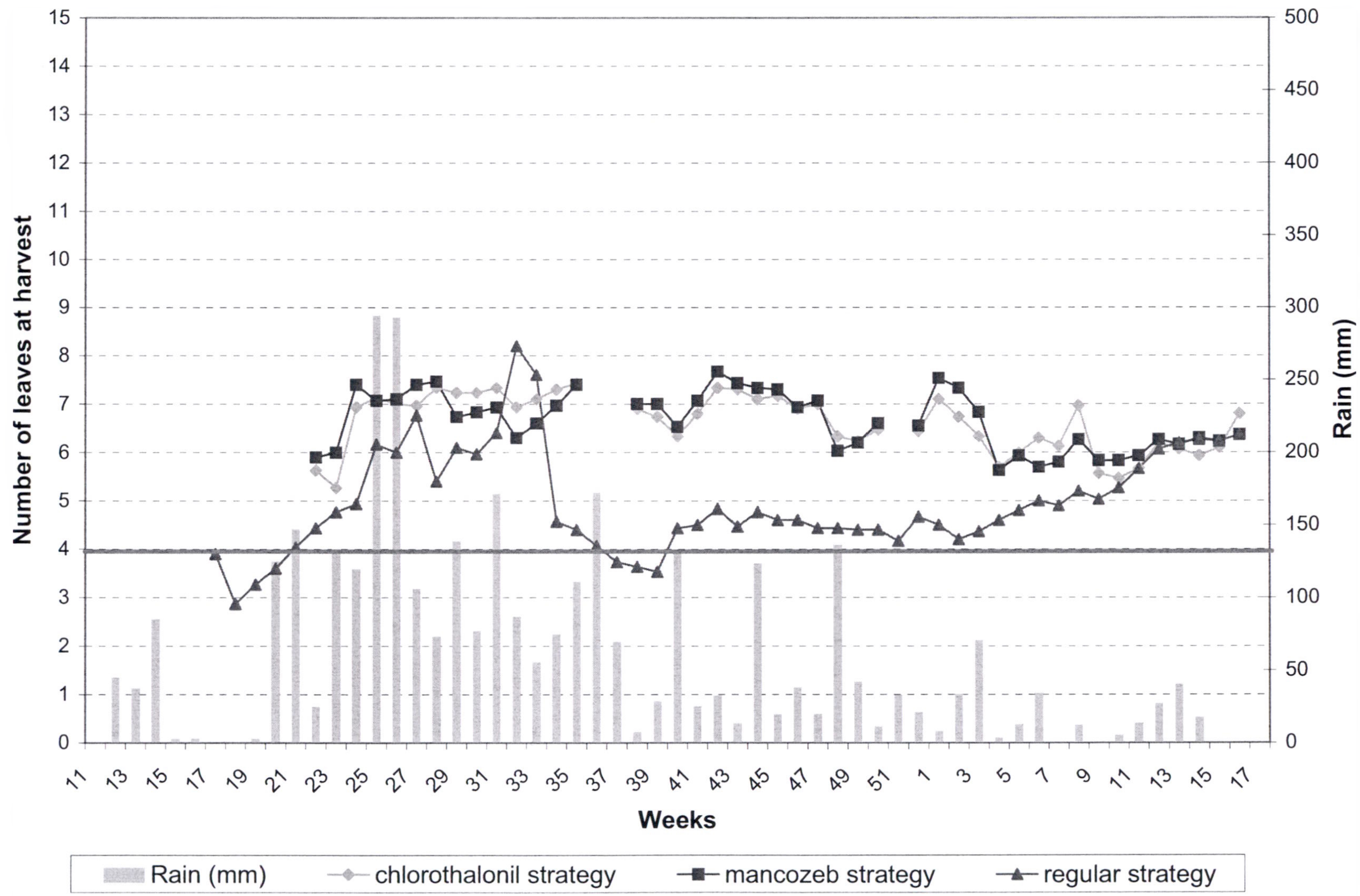
Criteria for BLSD assessment

BLSD control in 1990 using a forecasting strategy 12-15 apl/year



Fungicide applications are represented by arrows: antimitotics (red) and triazoles (black).

Criteria for BLSD assessment : NFLH



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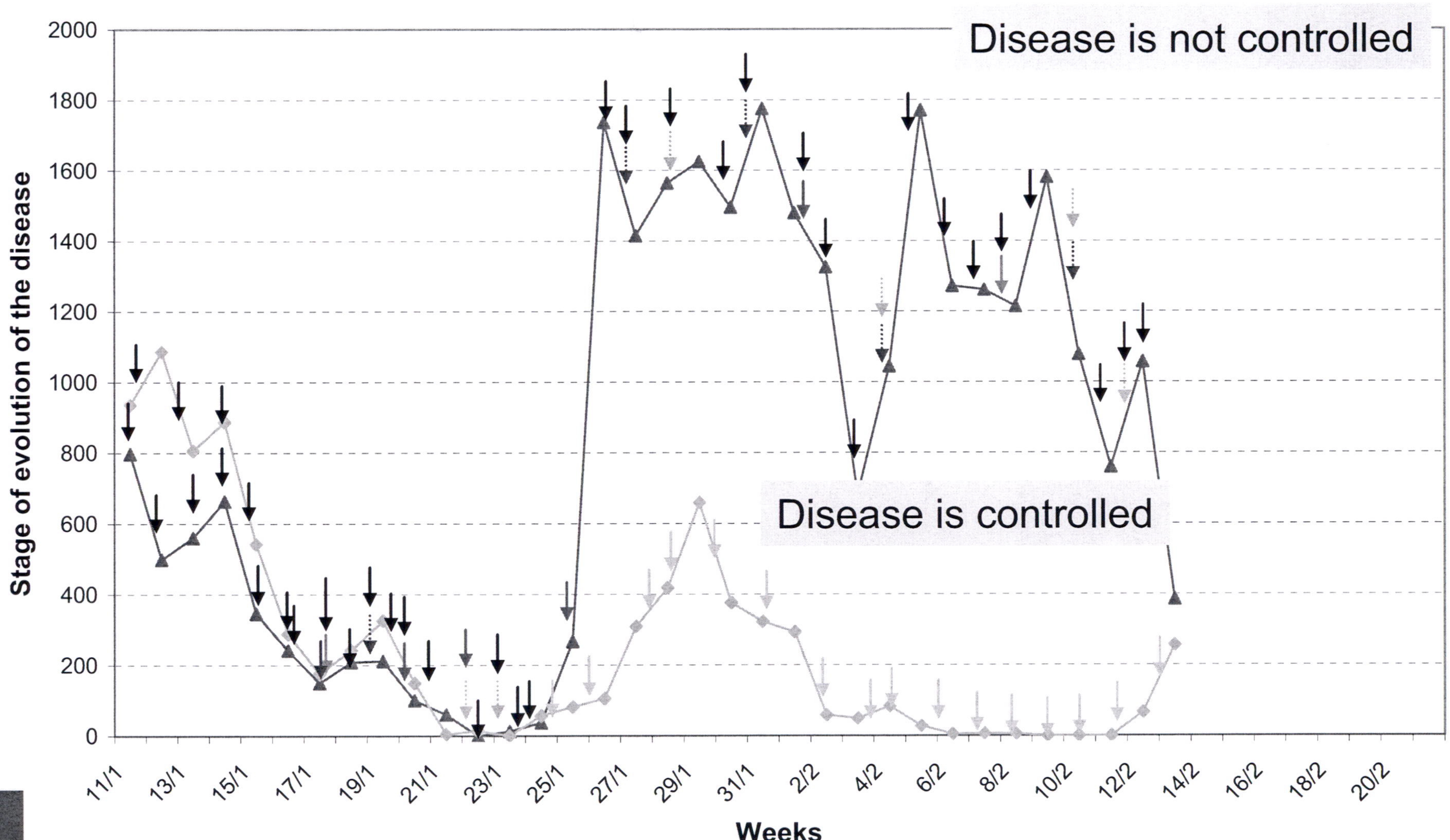
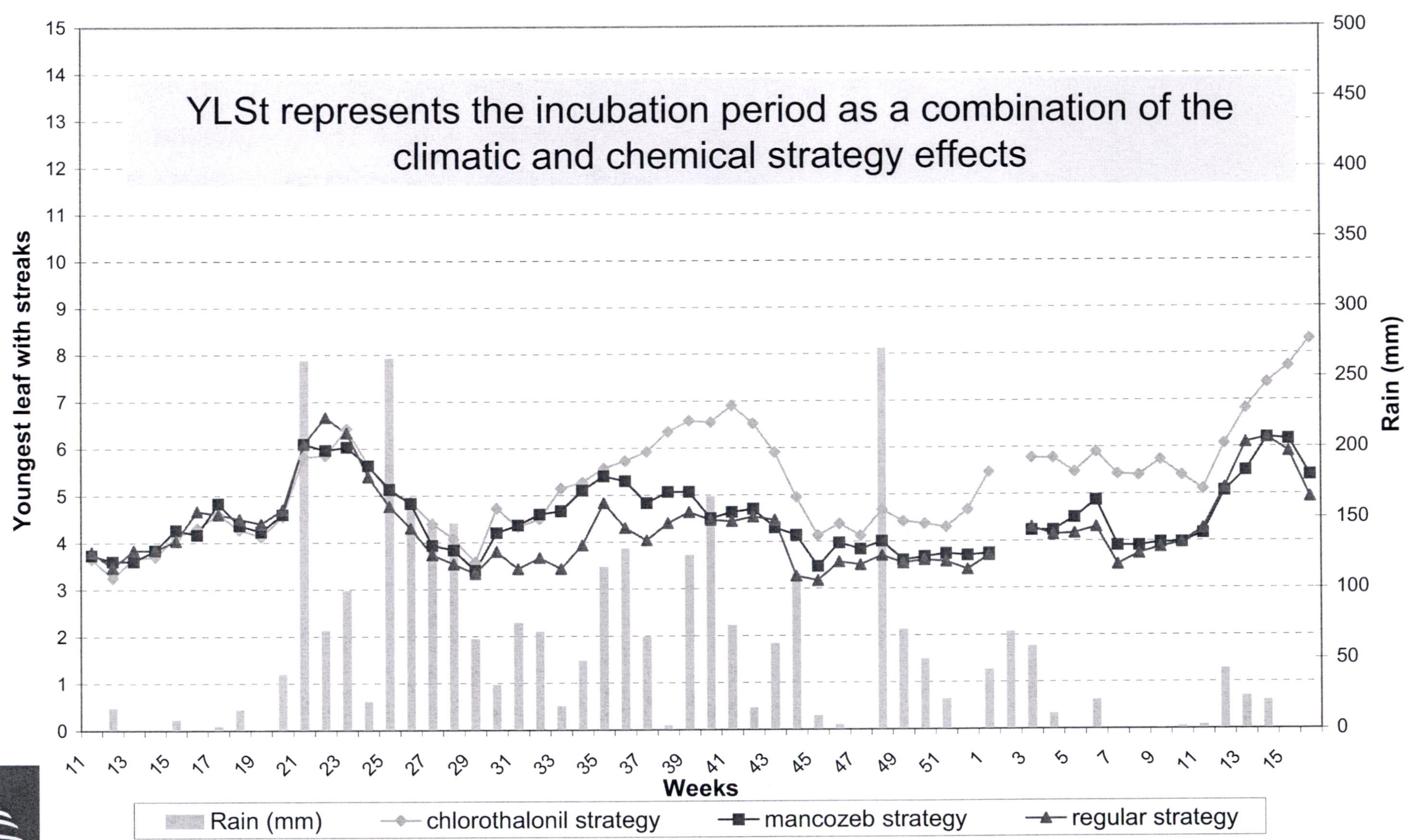
Criteria for BLSD assessment : SED



Criteria for BLSD assessment : YLSt



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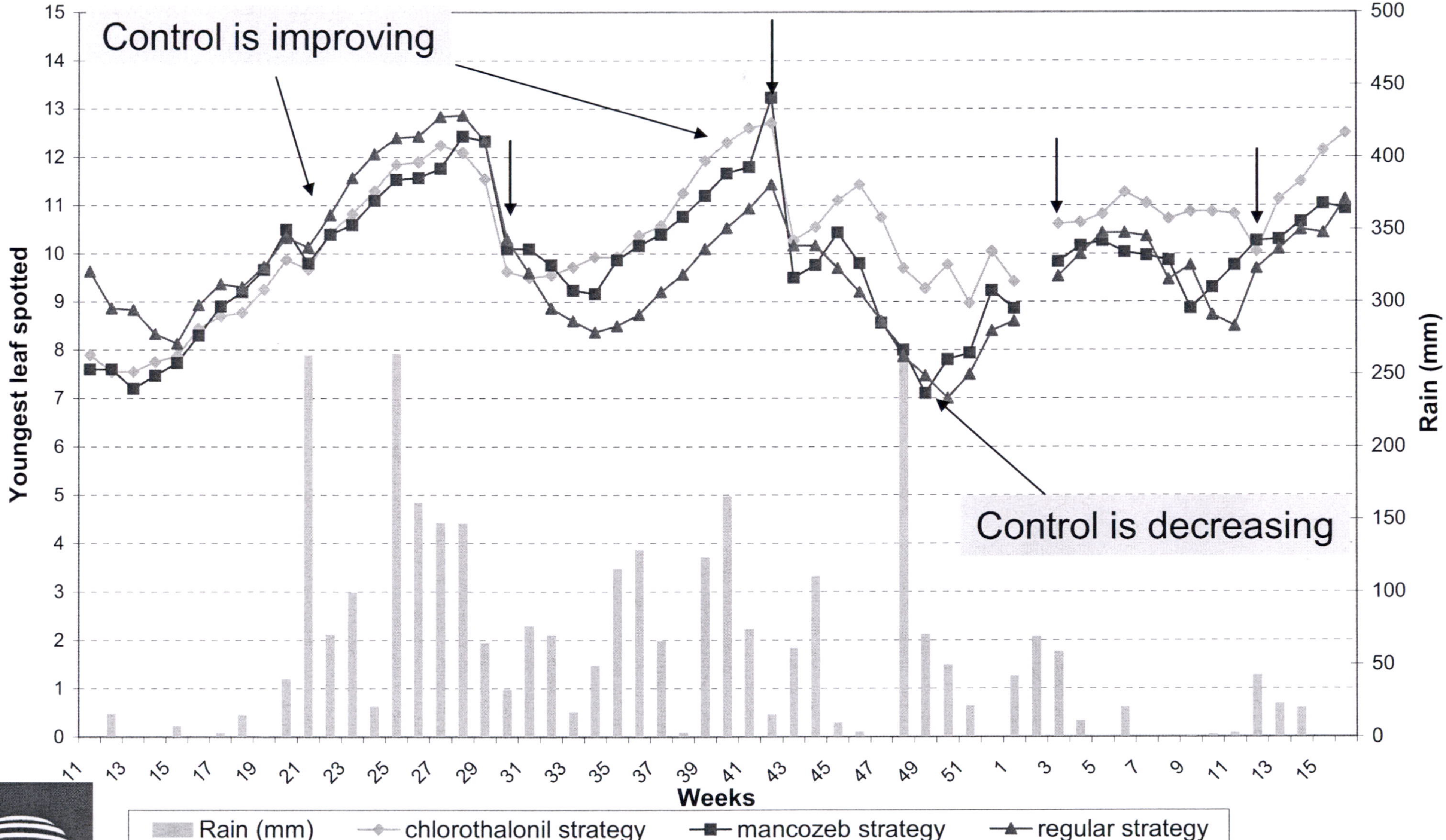
Criteria for BLSD assessment : YLS



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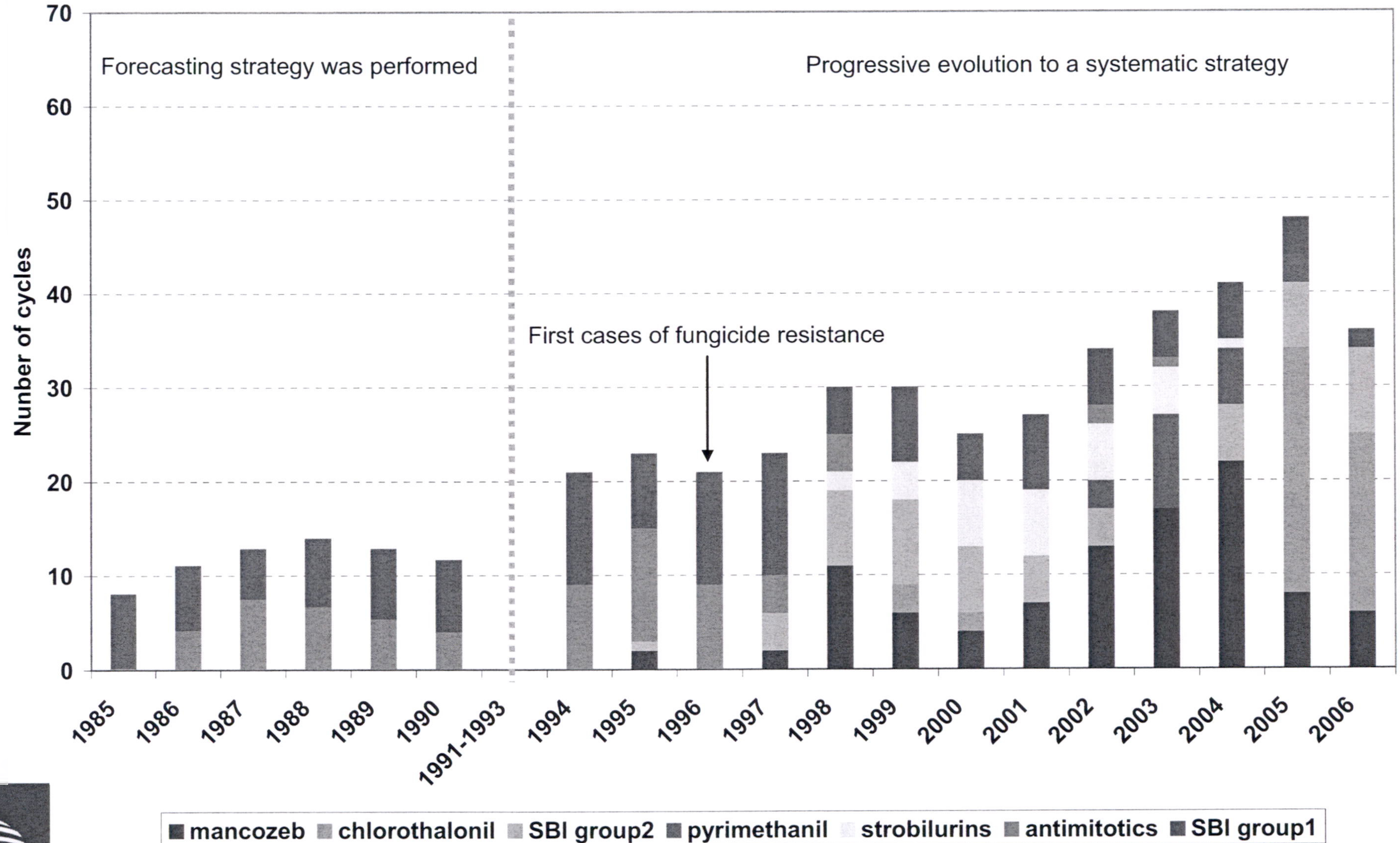
YLS evolution is a combination of foliar leaf emission rate and disease progression

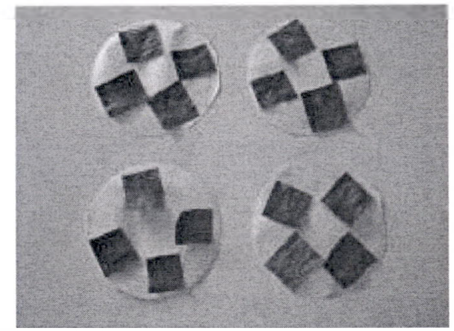
History of BLSD control in Cameroon



Fungicide resistance monitoring

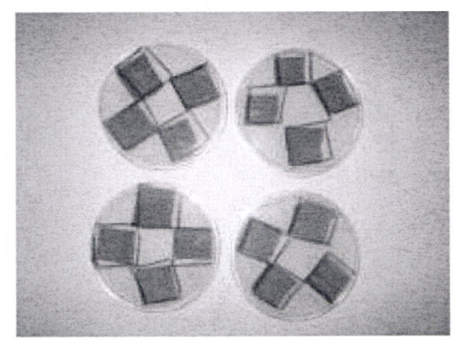
Methodology for the evaluation of fungicide resistance

Leaf sampling



Selection of lesions

Immersion in water



Projection of ascospores
on the plates

48 h

Microscopic observation
of germinating ascospores

Fungicide resistance monitoring

Situation of antimitotics : methyl-thiophanate 5 ppm

Years	% Resistant strains in the commercial plantation	% Resistant strains in the untreated plantation
1993	0	0
1994	0	0
1995	0	0
1996	15 (0-60)	0
1997	22	0
1998	46	0
2000	18 (14-21)	0
2002	52 (33-71)	0
2003	56	0
2004	37	0

First cases of resistance

Susceptible strains : germ tube are distorded or ungerminated

Resistant strain : germ tube germinate normally

Resistance is fluctuable

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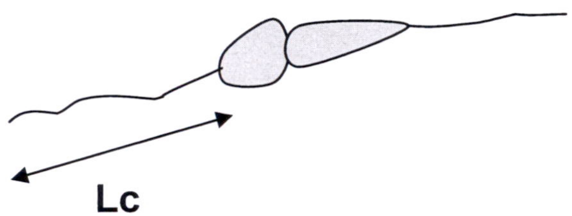
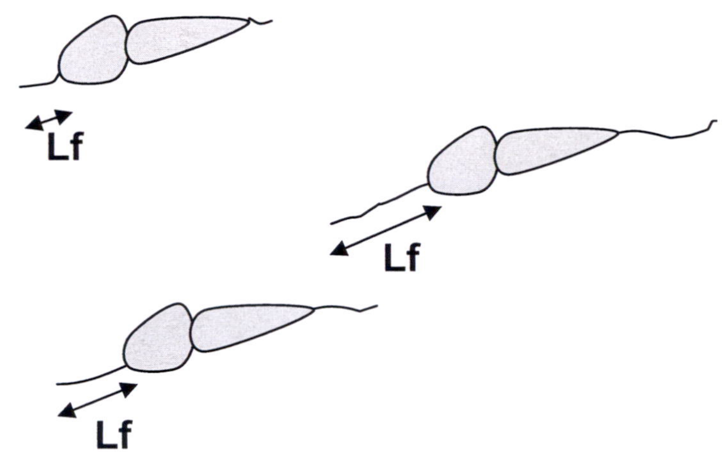
Fungicide resistance monitoring

Situation of IBS 1 : propiconazole

Ascospore germing on Agar



Ascospore germing on Agar plus fongicide



% growth inhibition (GI) = (1- Lf/Lc)x100

Fungicide resistance monitoring

Situation of IBS1 : propiconazol 0,1 ppm

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

Mean GI is lower in commercial plantations than in untreated areas

% ascospores with GI > 50% is lower in commercial plantations

Sensitivity to propiconazol is fluctuable

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Fungicide resistance monitoring

Situation of strobilurins : azoxystrobin 1 ppm

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

Fast development of resistant strains after 3 years of use
The level of resistance to strobilurins fluctuates : is it reversible ?

Strobilurins are no more used

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Consequences of fungicide resistance

- Strong increase of the number of treatments : 12-14 to 50 per year

  - increase of costs
  - increase of environmental effects

The amount of a.i./ha has increased by 40

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Consequences of fungicide resistance

How can we face this situation in order to minimize these negative consequences ?

(1) experiment fungicides having less negative environmental effects

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

These strategies would temporally exclude the use of systemic fungicides

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

CIRAD

Black Leaf Streak Disease improvement in Grenada

Limited economic impact for national market

- No resistant varieties used
- Low level of fungicide use (4-6 sprays/year)
- Control is poor but sufficient for a local market (situation of BLSD is going to worsen in the future)

Level of control does not fulfill with standards for international market

- This should be considered if exportation

CIRAD

1. Disease assessment

- Interest of disease assessments : take decisions, control chemical efficiency

- Information is too scarce for any use : no more than 5 reports over a one year period (far from 52 reports/52 weeks ....)

-Information should be taken on weekly basis :

Suggestion :

•Focus collecting data on reference spots evaluated on weekly basis

•Information on same plants for continuous history

•Extend criteria : NFLH, SED, YLS, YLSt

•Measure climatic data suc as Piche Evaporation (climatic forecasting)

CIRAD

2. The chemicals

1. Fungicides are not used at a proper rate:

- The same pattern of rate is not the same in all the Sigatoka Team

ex: Tilt : 180 to 360 ml/ha (correct rate is 400 ml/ha)

- Measurements of rates is not accurate : no guarantee that the right rate is used

- Rates are not correct for most fungicides and too low (low efficiency, risk of resistance):

ex: Bankit : rate is 100 ml/ha instead of 400ml/ha; Sigma : rate is 350 ml instead of 800 ml/ha ; Tilt : rate is 180 ml ? Instead of 400 ml

CIRAD

2. The chemicals

2. Formulations of fungicides are not properly used :

- According to formulations, an adjuvant should be added :

ex: Bankit SC is not miscible in oil

-More attention should be paid to the formulations used :

ex: the strobilurin Tega EC should be preferred to Bankit SC for application in oil

2. The chemicals

3. Levels of sensitivity to the fungicides are unknown:

Suggestions:
Evaluate the sensitivity of M. fijiensis to systemic fungicides as soon as than possible (important to define baseline sensitivities)

Manage properly fungicide resistance : alternation of different mode of action fungicides (antimitotics, SBI group 1, strobilurins).

Strobilurins should be used very carefully : high risk of resistance enhanced by high levels of populations

CIRAD

2. The chemicals

4. The method of application : ground spraying has a limited capacity :

2 teams : 20 ha/day – 100 ha/month

1 plane : 200-500 ha/day; 1 helicopter : 100 to 200 ha/day

Suggestion:
Right calibration of ground spraying in order to ensure that a proper rate of a.i./ha is used

If export is envisaged : aerial applications with ULM could be used

3. Management of inoculum

- Chemical control is only a part of BLSD control

- Deleafing of spotted leaves is important :

- Ascospores are produced in necrotic stages for a long time. Leaf spot must be removed

- Leaf spots reduce fruit quality (reduction of greenlife) and should be removed from shooting plants

Suggestion : improve implication of banana growers on inoculum management (training, incitation)

CIRAD

4. Resistant banana cultivars

Since local market has less requirements in terms of greenlife duration and conservation properties, other dessert cultivars than Cavendish bananas could be used in cropping systems, and particularly cultivars with resistance to BLSD:

This is the case in Asia and Brasil, for local market cultivars

Suggestion : introduce dessert cultivars with resistance to BLSD to replace chemical control which is not very efficient and sustainable in Grenadian conditions

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5. Training

BLSD arrival in Grenada is recent, it is important to reinforce the ability of MOA services with a better knowledge of BLSD control :

-Disease assessment methods

-Fungicide use

-Resistant varieties

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