



# BANANA value-chain







## > Banana cropping system

### A soil-plant reference system for managing mineral fertilisation

In the late 1980s, Cirad developed a soil-plant reference system helping planters to optimise banana plant fertilisation.

To ensure optimum banana plant fertilisation, we need to know the relationships between the nutrient contents of the soil and the banana plant, and its productivity. Diagnostic surveys conducted in Guadeloupe and Martinique in the late 1980s helped establish these relationships and determine optimum values to achieve in the soil and the plant. This work was

supplemented by behavioural studies on soil exchange of the main elements necessary for banana plant growth, such as potassium. This knowledge was collated and used to determine fertiliser formulae suited to banana plantation soils in the French West Indies, and provide a technical reference system for managing fertilisation based on soil and plant analyses. ■

Leaf sampling for banana plant nutrition diagnostic.



#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- This soil-plant reference system has been used for many years to manage fertilisation and define fertiliser formulae suited to various soil types, which explains the good current nutritional state of the FWI banana stock.
- These formulae are disseminated in the "Planter's manual" by producers' groups, and all FWI producers have access to them.

#### > BACKERS AND CONTRIBUTING PROJECTS

- Producers
- Operational programme

#### > CONTACT

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#### > FIND OUT MORE

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## > Planting

### Vitroplants on remediated soil to manage soil-based bioaggressors

The definition and application of the principle “planting healthy stock on remediated soil” by Cirad and IRD represent the basis of innovative crop management systems providing integrated protection against soil-based bioaggressors. They helped reduce by more than 65 % between 1996 and 2011 the use of chemical pesticides (mainly nematicides and insecticides) against these parasites.

Use of traditional planting stock [stumps with attached sprouts, “sword suckers”, etc.] has long been a source of unintentional dissemination of soil bioaggressors in banana cropping systems. In Martinique and Guadeloupe,

they are represented primarily by phytoparasitic nematodes (complex of microscopic round worm species parasitizing the root system and rhizome tissue of banana plants) and by the weevil *Cosmopolites sordidus*, a borer insect whose larvae dig tunnels in the rhizome. Most of these parasites weaken the plant and alter its rooting in the soil, which leads to longer cultivation cycles and big yield losses for producers.

The work of Cirad and IRD to halt the development of these bioaggressors has helped establish a basic principle of sanitary preventive treatment for banana cropping systems: combining eliminating soil-based parasites from soils with the use of vitroculture plant stock. Banana vitroplant production and weaning techniques have been progressively refined in conjunction with producers and nursery operators. Vitroplants today represent a homogeneous, high-quality stock, strictly free from nematodes and weevils. Those produced by Vitropic, a Cirad subsidiary, are in addition indexed against several banana plant viruses and pathogenic bacteria.



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Banana vitroplants in a weaning nursery.

#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- The majority of FWI banana industry producers (more than 60%) have taken up these results, and apply them on their plantations.

#### > BACKERS AND CONTRIBUTING PROJECTS

- CPER projects
- SPD
- Sustainable Banana Plan (2007-2015)

#### > CONTACTS

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> **Planting**

**Vitroplants on  
remediated soil to  
manage soil-based**

Soil remediation from banana plant phyto-parasitic nematodes is based on fallow or crop rotation techniques not allowing either banana plant regrowth (due to contamination) or host plant regrowth (e.g. other crops, weeds or service plants sen-

sitive to these nematodes). In the case of the weevil, this remediation is promoted by mechanical destruction of residue of the old banana crop, so as to speed up the disappearance of resources and habitat that this residue represents. ■



Banana  
vitroplants  
in the field,  
and crop  
rotations based  
on legumes  
or grasses.

> **FIND OUT MORE**

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## > Combating the banana weevil

### Biological control by trapping



*Cosmopolites sordidus*,  
the banana weevil.

The main banana plant pest, the weevil was long controlled chemically (chlordecone), until biological solutions were implemented thanks to advances in knowledge of insect biology, its movements in the banana plantation and its natural predators.

The banana weevil *Cosmopolites sordidus* is the main banana plant insect pest. Its larvae bore tunnels in the banana plant bulb, potentially toppling the plants and altering their ability to uptake water and mineral elements from the soil. The adult wanders over the ground, to gradually colonise the plots close to it. A partnership with Inra and private partners helped develop adult trapping equipment, combining a specific attractant (sordidin, an aggregation pheromone) with a pit trap. These traps are used for monitoring population changes, and capturing weevils en masse from cultivated plots in order to prevent colonisation of healthy plots.

Optimisation of this trapping on cultivated or fallowed plots made it necessary to understand the factors influencing adult movements. To this end, Cirad employed radio-telemetry to study weevil movements on plots with various banana planting systems. It then developed simulation models to enable virtual testing of innovative organisation strategies for crops, fallow and trapping. This new knowledge is helping optimise spatial and temporal setting of traps (trapping in fallow, on the border around healthy plots, etc.).

So trapping supplements the preventive measures based on use of sound planting

Pheromone trap (top); weevil larvae and damage in a banana plant bulb (bottom).

material, vitroplants (banana plants derived from vitroculture).

Furthermore, in order to generate more management levers, Cirad has also studied how to promote weevil control by means of its natural predators (other arthropods). This management mode is based on modifying the flora of the plots, by inserting service plants which promote generalist predators of weevils. ■



#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- Trapping has been adopted by 80% of banana producers.
- Primary prevention based on use of vitroplants is widely used on dessert banana plantations.
- In Martinique, private companies have been set up offering weevil trapping services to farmers.

#### > BACKERS AND CONTRIBUTING PROJECTS

- EAGGF Martinique 2000-2003 "Promoting the development of sustainable cropping systems"
- ERDF Diren 2003-2006 "Reducing the environmental impacts of crops, part 1: Integrated and alternative pest management"
- ERDF 2007-2013 "Designing innovative cropping systems"

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#### > FIND OUT MORE

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## > Banana sigatoka diseases

### A coordinated biological warning system for rational management, limiting fungicide treatments

In the FWI, Cirad has developed and fine-tuned a biological warning system which helps greatly limit the number and impact of fungicide treatments against Sigatoka diseases (6 to 8 treatments per year, as opposed to 40 to 70 in countries not using this system).

**B**anana Sigatoka diseases are fungal diseases which cause significant foliage necrosis. They also lead to yield losses and reduce the export potential by causing early maturation of the fruit. There are two types of Sigatoka disease: yellow Sigatoka (*Mycosphaerella musicola*), present in the FWI since banana cultivation began; and black Sigatoka or BLSD (*Mycosphaerella fijiensis*), a more

devastating variety, which reached Martinique in 2010 and Guadeloupe in 2012. Export banana cultivation requires the use of fungicide treatments in most banana production zones. To limit the risks of early ripening, treatments are applied systematically every week in order to protect the new leaves produced by the banana plants. Thus 40 to 80 treatments are applied every year to combat these diseases in Latin American and African countries.

Cirad has developed and fine-tuned in Martinique and Guadeloupe a biological warning system which helps greatly limit the number and impact of fungicide treatments [1 kg/hectare/year instead of 30 to 60 kg/hectare/year]. This system also makes it possible to tailor the number of treatments to the climate of different zones [1 to 12 treatments per year]. It comprises technical and organisational aspects.



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Observer at work identifying the initial stages of black Sigatoka.



Young stages of the disease.

## > TRANSFER STAGE AND DISSEMINATION LEVEL

- This system has been implemented against yellow Sigatoka in Guadeloupe since the early 1970s, enabling big reductions in the number of treatments. Since then, it has been extended to all banana producers in Guadeloupe and Martinique. Cirad designed and administered the system, and then transferred it to producers' groups which rapidly became its custodians via technical units (Sica-TG in Martinique and Serviproban in Guadeloupe). These two islands have become world benchmarks in rational management of this disease.

## > BACKERS AND CONTRIBUTING PROJECTS

- Producers
- Sustainable Banana Interreg. Project, Caribbean
- Sustainable Banana Plan, EAFRD, 2007-2015

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> **Banana sigatoka diseases**

A coordinated biological warning system for rational management, limiting fungicide treatments

**TECHNICAL ASPECTS**

- > Early detection of new infestations is becoming the basis for activating treatments. A biological indicator (state of development, SD) is calculated based on observations made every week on a plot of 10 banana plants monitored regularly until flowering.
- > The powerful curative effect of the treatments, which is based on use of systemic fungicides in combination with mineral oil.
- > Integrated disease management, especially by means of preventive

practices (defoliation of necrotic stages) and agronomic practices.

**ORGANISATIONAL ASPECTS**

- > Centralisation of decision-making processes (activation and application of treatments) in a single technical unit helps rationalise management over the entire banana planted area.
- > Dividing the banana planted area into homogeneous treatment zones covering several producers.
- > A system of cooperation between producers for complete funding of pest management. ■



Foliar damage of Sigatoka.



## > Black Sigatoka

# A regional observatory for monitoring resistance to fungicides and better controlling the disease

Cirad has set up a regional network for monitoring resistance to fungicides used in combating black Sigatoka, so as to tailor the management strategies.

Rational management by means of banana Sigatoka warning systems has helped significantly reduce the number of treatments required to control these diseases in the FWI. This management method is based on using systemic fungicides with a powerful curative action, which penetrate into the plant and are used at low dose (unlike the contact fungicides which are employed in Latin America and Africa, systematically and weekly, and at high doses). However, the risk of strains resistant to these fungicides appearing is high, which in the long term may threaten the sustainability of this warning-based management. So it is essential to continuously monitor the development of fungicide sensitivity due to the fungi responsible for these diseases, in order to tailor management strategies.

In order to effectively manage black Sigatoka, Cirad has set up a regional

monitoring network based on technical improvement of resistance assessment methods, but also on implementing concerted actions on a Caribbean scale.

### IMPROVING THE RESISTANCE ASSESSMENT METHOD

Resistance assessment consists in germinating and measuring the resistance of the fungus spores in the presence and absence of various fungicides. The response of a population of spores from a treated plantation is compared with that of a population taken from an untreated field.

The reference method generally employed uses fungal ascospores (sexual reproduction spores found in necrotic stages). However, several major drawbacks make this ascospores test impossible or unreliable.

### > TRANSFER STAGE AND DISSEMINATION LEVEL

- The resistance assessment technique is currently used on a routine basis in aid of the various Caribbean islands in a benchmark laboratory located outside the production zone, at Cirad Montpellier (UMR BGPI). It is also in the process of transfer to a laboratory in the Dominican Republic (JAD).
- The first resistance assessment measures have already helped adapt the management strategies implemented in the various islands, and therefore relate to all the export banana producers in the Caribbean.

### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable banana Interreg. Project, Caribbean, 2007-2015
- Sustainable Banana Plan, EAFRD, 2007-2015
- BAM project in the Dominica Republic

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### > FIND OUT MORE

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Collecting conidia on pure fungus cultures for the germination test.



Regional training network.



> **Black Sigatoka**  
A regional  
observatory for  
monitoring resistance  
to fungicides and  
better controlling the  
disease

The method developed and optimised by Cirad is based on composing monospore populations based on conidia (asexual reproduction spores) produced on young foliar lesions due to the disease which are easily sampled in the field. The fungus is then cultivated artificially in order to produce conidia, which will then be used for the germination tests.

**CONSTRUCTION OF A REGIONAL  
CARIBBEAN OBSERVATORY**

The high dispersion capacity of the fungus facilitates the propagation of resistant strains from island to island in the Caribbean. As the arrival of black Sigatoka in the Northern Caribbean goes back further (1996 for the Dominican Republic) than in the Southern Caribbean (2009 on St Vincent and 2012 for Guadeloupe), and the treatment histories vary between islands, there is a real disparity of the risk of resistance appearing, depending on the geographic zones in question. Yet this risk needs to be assessed in order to anticipate

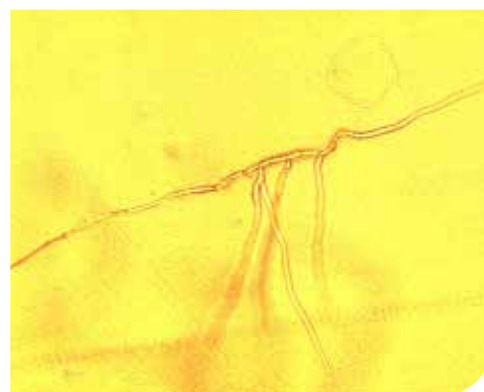
losses of fungicide effectiveness in the field. When black Sigatoka reached the Caribbean, there were no local structures able to perform this resistance monitoring for the islands affected. Thus to build a suitable management strategy and define the risks of inter-island influences, a regional collaboration led by Cirad was implemented. It is based on three types of action:

- > Annual collection of samples on various Caribbean islands (Martinique, Guadeloupe, Dominican Republic, Santa Lucia, Dominica, Saint Vincent) and performing analyses in a benchmark laboratory based in Montpellier.
- > Training technicians from the various islands in the various methods of laboratory-based resistance assessment.
- > Supporting local initiatives for measuring fungicide resistance and for defining rational strategies for fungicide use, helping better manage the risks of the appearance and development of resistant strains. ■

Sensitive strain



Resistant strain







## > Black Sigatoka

### An “integrated” management strategy as an alternative to chemical management

Cirad has developed integrated protection for the banana plant against black Sigatoka. This involves combining several cropping practices as mechanisms to limit the development of the disease and help the plant withstand damage better. This innovative approach represents a world first.

**B**lack Sigatoka is one of the major parasite burdens on export banana cultivation. This disease caused by the fungus *Mycosphaerella fijiensis* causes a considerable reduction in the foliar surface area of the banana plants, and causes considerable yield losses. It causes early maturation of the fruits, which are then non-exportable.

#### AN OBJECTIVE: REDUCE CHEMICAL MANAGEMENT

The banana industry currently uses Cavendish as the export variety. This productive variety is also highly sensitive to black Sigatoka, and export cultivation, especially in the wet tropics, is only currently possible by means of continuous

Young banana plant plot undergoing chemical-free integrated management of black Sigatoka.. © C. Guillermet



#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- This integrated management system has been trialled by two volunteer producers in the Dominican Republic and Martinique.
- In Guadeloupe, this method is starting to undergo real-life situation assessment, with a pioneer producer. Work is underway to optimise defoliation practices and to identify new mechanisms which can be integrated into this management method.
- This work has helped raise producer awareness of the importance of regular sanitary defoliation.

#### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable Banana Plan, EAFRD, 2007-2015
- Sustainable Banana Interreg. Project, Caribbean, ERDF, 2009-2015

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> **Black Sigatoka**  
An “integrated”  
management  
strategy as an  
alternative to  
chemical  
management

> **FIND OUT MORE**

Conception et évaluation de systèmes de culture pour cultiver des variétés sensibles de Cavendish sans lutte chimique contre la MRN. De Lapeyre de Bellaire L., Guillermet C., Le Guen R., Fouré E., Dorel M., Lescot T., Abadie C., Chillet M., 2013. In : Séminaire International sur les Cercosporioses et la production de banane durable = International Workshop on Black Sigatoka Control and Sustainable Production of Banana in the Caribbean, Gosier, Guadeloupe, 25-27 juin 2013. Cirad, UGPBAN, IT<sup>2</sup>.

Growing Cavendish bananas without chemical control of black leaf streak disease. Guillermet C., Fouré E., Dorel M., Lescot T., De Lapeyre de Bellaire L., 2013. In : Proceedings of the 20th international meeting ACORBAT: 40 years sharing science and technology, Fortaleza, Brazil, 9-13 September 2013. eds. Borges A.L., Lichtemberg L. s.l. : s.n., 159.

Lettre du Plan Banane Durable Caraïbe n°8 : <http://asp.zone-secure.net/v2/index.jsp?id=2825/3662/32352&lng=fr>

chemical control. In most banana producer countries, fungicides are the most commonly used pesticides for this phytosanitary protection. This chemical control is regulated in France by increasingly restrictive regulations. Nowadays, managing this disease without any chemical treatment represents a major challenge for the agro-ecological transition of export banana cultivation.

To explore alternatives to this chemical management, Cirad has developed an integrated protection system employing a combination of several cropping practices as mechanisms to limit the development of the disease and help the plant withstand damage better. This innovative approach represents a world first.

**SLOW THE DEVELOPMENT OF THE FUNGUS, BY LIMITING ITS ABILITY TO REPRODUCE AND DISPERSE**

By eliminating the most advanced lesions of the disease (necrotic stages), the quantity of inoculum in the plot can be eliminated. Necrotised banana leaves produce spores which can be disseminated by the wind over long distances (up to more than one kilometre).

**PROMOTING OPTIMUM PLANT GROWTH AND LIMITING DAMAGE TO THE FRUIT QUALITY**

Thanks to high-precision agronomic management in terms of fertilisation, irrigation and control of other pests, a high foliar emission rate can be maintained, offsetting the decrease in foliar surface area caused by the disease. In this way yield losses can be limited. Furthermore, Cirad's work has demonstrated that foliar necroses directly cause early fruit maturation. The practice of mechanically defoliating necroses during the fruit filling-out phase, associated with optimum

prediction of the fruit harvest date, helps limit the effects of the disease on ripening.

Under these conditions, harvested fruits retain a preservation time compatible with export, even if the banana plants have a tiny number of leaves upon harvesting (less than one leaf!). This result calls into question the usual standards required for export: since at least 4 to 5 leaves are required upon harvesting for a cluster to be considered exportable. Furthermore, in the contexts studied, yield losses were variable and limited. This aspect deserves further investigation in other situations, and over a longer period. ■



Banana plants ready for harvesting after major defoliation (Dominican Republic).

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## > Sustainable Banana Plan

### A dialogue platform to help producers design innovative and environmentally-friendly cropping systems

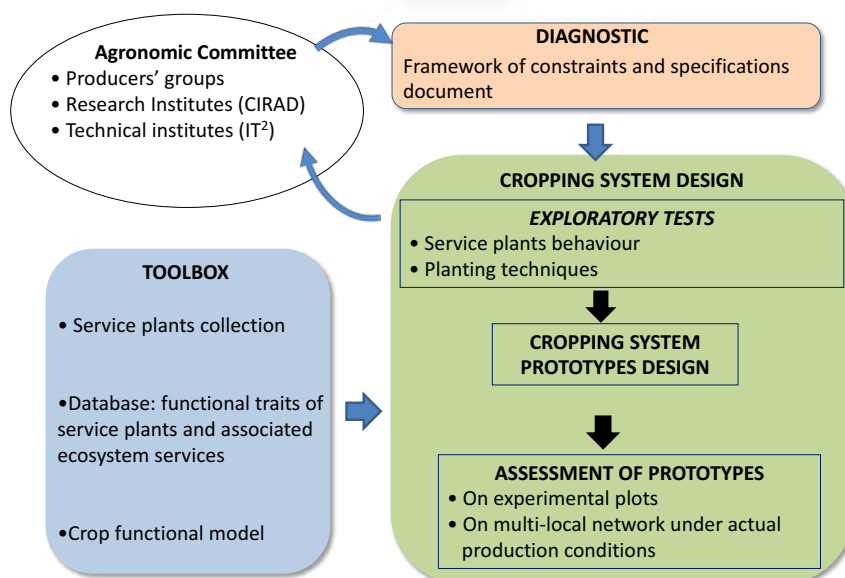
One of the major challenges for sustainable banana production in the FWI is to reduce the environmental impacts of this crop. Cirad and IT2 have set up an “Innovative cropping systems” platform under the Sustainable Banana Plan. Its objective: to build the innovation capacities of the banana production industry in Guadeloupe and Martinique.

This innovation platform is aimed at developing sustainable cropping systems, in concert with the various banana production players (researchers, engineers, technicians, producers, groups, etc.). These systems are based mainly on use of service plants as an alternative to chemical inputs, and incorporate the principles of agro-ecology.

The platform (the organigram of which is presented below) has helped create

and then transfer to banana producers in Guadeloupe and Martinique cropping systems enabling them to do without nematicide or insecticide treatments and mechanical tilling, and to reduce use of herbicides and fungicides. These new types of cropping systems restore biodiversity within the banana agrosystem, and provide ecosystem services such as biological regulation of bioaggressors, or recycling of soil nutrients. ■

#### “Innovative cultivation systems” platform



#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- The success of the “Innovative Cropping Systems” platform can be gauged by means of the significant fall in chemical inputs used in banana production (> 50 % since 2008), and by the increasing proportion of producers employing the innovative techniques suggested.

#### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable Banana Plan, EAFRD, 2007-2015

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#### >> FIND OUT MORE

<http://www.bananeguadeloupemartinique.com/le-plan-banane-durable-moteur-du-progres>





## > Mulch planting

# Biological ploughing to replace mechanical tilling

Cirad proposes replacing mechanical tilling prior to planting by biological ploughing, using a service plant. Planting is then carried out directly on a plant bedding covering the soil. This innovative practice reduces the impact of the crop on climate change.

Cirad has developed an innovative banana plantation replanting technique which combines cultivating a plant which naturally restores soil porosity via its root system ("biological ploughing"), and covering it with a bedding of plant residue.

This technique represents an agro-ecological alternative to mechanical tilling. Usually applied when replanting banana plantations, mechanical tilling has adverse effects on soil quality, but also on the environment. This practice

actually accelerates erosion, reduces fertility (physical, biological and chemical) and removes carbon stored in the surface layers of the soil. It also employs heavy machinery with a high fossil energy consumption, thereby contributing to increasing greenhouse gas emissions.

Cirad's "biological ploughing" technique improves not only the soil quality, but also contributes to reducing the impact of the crop on climate change. ■

### > TRANSFER STAGE AND DISSEMINATION LEVEL

- This technique is disseminated in the Planter's Manual of the producer groups
- It is implemented on nearly 30% of banana plantations in Guadeloupe and Martinique.

### > BACKERS AND CONTRIBUTING PROJECTS

- SPD "Banana industry support" project, 2000-2007 (EU-State-Region)

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### > FIND OUT MORE

Dorel M., Lakhia S., Pététin C., Bouamer S., Risède J.M. 2010. No-till banana planting on crop residue mulch: effect on soil quality and crop functioning. *Fruits* vol. 65, p. 55-68

<http://www.it2.fr/documentation/manuel-du-plantateur-fr>

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Non-tilled banana plantation with a bedding of service plants (*Brachiaria decumbens*).







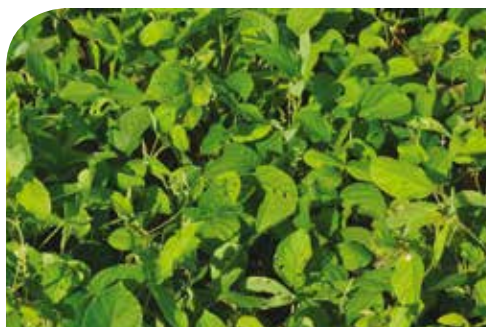
## > Sustainable Banana Plan

### Cropping systems harnessing biodiversity using service plants

Within the “Innovative Cropping Systems” platform, Cirad is developing banana cropping systems based on implementing agro-ecological alternatives to chemical inputs. These systems harness biodiversity using service plants.

Around ten types of innovative cropping system have been developed by Cirad, with the participation of producers and various players in banana production. These include for example:

#### Perennial soy remediating fallow cropping system, with banana plants replanted on the living cover



**Remediating fallow**  
(perennial soy)

- > Nematode control
- > Improved soil fertility



**Planting on a living cover**

- > Erosion protection



**Maintaining plant cover under the banana plants**

- > Weed control

#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- These systems have been adopted by 20 % of producers, and are being constantly improved by a group of pioneer producers, in conjunction with the innovative cropping systems platform of the Sustainable Banana Plan.

#### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable Banana Plan, EAFRD, 2007-2015

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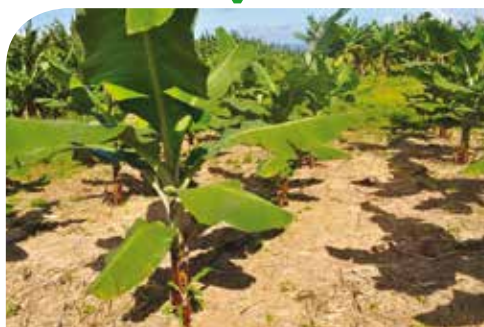
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- > **Sustainable Banana Plan**  
Cropping systems harnessing biodiversity using service plants

**Brachiaria and Crotalaires remediate fallow system, with banana plants replanted on the dead cover**



**Remediating fallow**  
(Brachiaria/Crotalaria)

- > Production of diversified biomass
- > Restoration of soil fertility
- > Bioaggressor regulation
- > Carbon storage

**Destruction of plant cover**

**Planting banana plants under dead cover**

- > Restoration of nutrients
- > Soil protection against erosion

These basic techniques were developed and then disseminated to producers, by means of benchmark plots used to assess prototype cropping systems, and then adapt them to actual production conditions.



## > Sustainable Banana Plan

### Alternatives to using herbicides on banana plantations

At present herbicides remain the main use of pesticides in banana cultivation. They are applied to destroy banana plantations when fallowing the plots, and for weed control. Alternatives to herbicide use have been tested by Cirad, and proposed to banana producers.

#### Cattle grazing

Used to effectively destroy the banana plants when fallowing the plots without employing herbicides or heavy mechanisation which would damage the soil structure and alter its fertility.



Banana plantation destroyed by grazing cattle.

#### Various weed control techniques

> Laying on the soil surface mulch comprising either exogenous materials (bagasse, green waste), or endogenous



Bagasse mulch.

materials (plant cover mulched down at the end of the fallow period).

> So-called "service" plants tailored to various climate zones.



Impatiens cover under high-altitude banana plantation.

> Mechanical control of spontaneous plant cover with a light tractor equipped with low-pressure wheels.



Gyro-mulching of spontaneous cover.

#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- These alternative plant cover control methods have been adopted by 20% of producers.

#### > BAILLEURS ET PROJETS CONTRIBUTEURS

- Sustainable Banana Plan, EAFRD, 2007-2015
- Sustainable Banana Interreg. Project, Caribbean, ERDF, 2009-2015

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#### > FIND OUT MORE

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<http://www.it2.fr/documentation/manuel-du-planteur-fr>  
<https://drive.google.com/file/d/0BxIDA5mXa72aN1VTOWRSa3p6Slk/view>







## > Sustainable Banana Plan

### A dialogue platform service to help producers create and select new banana varieties

A participative platform was set up in 2009 under the Sustainable Banana Plan to create and select banana varieties meeting the needs of professionals and consumers.

This collaborative platform comprises fifteen or so researchers, engineers and technicians from Cirad and IT2. It contributes to innovation capacity building in the banana production industries of Guadeloupe and Martinique. It is aimed in particular at creating and selecting new banana varieties:

- tolerant to bioaggressors, in particular black Sigatoka, a serious banana fungal disease
- with high production potential,
- suited to the constraints of the export industry,
- with taste quality appreciated by consumers.

**From 300 hybrids produced per year in 2007 to 1200 in 2014!** The platform structuring, combined with an increase in the resources involved, has helped creation capacities surge, from 300 hybrids produced per year in 2007 to 1 200 in 2014.

pre- and post-harvest parameters, and call on several disciplines: genetics, phytopathology, agronomics and physiology. After an initial observation phase, the hybrids that do not meet the characteristics sought are eliminated. This is known as “negative” selection. Fewer than 10 hybrids per year pass this initial phase! The hybrids selected are reproduced to 25 individuals, to enter the second phase, the so-called “positive” selection phase.

#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- 5 608 hybrids produced from 2009 to 2014, 23 hybrids assessed in selection phase 2, namely hybrids CIRAD 930 to 952. .
- 6 plant improvements filed for dissemination of varieties: CIRAD 916, CIRAD 918, CIRAD 920, CIRAD 921, CIRAD 924, CIRAD 925.
- 1 variety, CIRAD 925, in development phase with pioneer producers in Martinique and Guadeloupe, and in the downstream segment.

#### > INTELLECTUAL PROPERTY

- Variety patent holder: Cirad

#### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable Banana Interreg. Project, Caribbean, 2009-2015
- Sustainable Banana Plan, EAFRD, 2007-2015

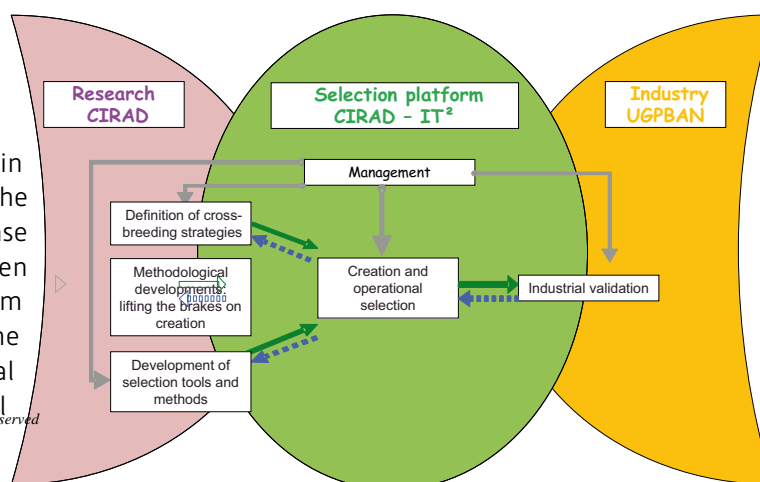
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Platform schematic

#### THE TWO VARIETY SELECTION PHASES ON THE EXPERIMENTAL STATION

At the Neufchâteau station in Guadeloupe, Cirad is conducting the initial hybridisation creation phase (natural cross-breeding between 2 parents), using banana plants from the collection managed by the Biological Resources – Tropical Plants Centre. The varietal selection methods developed by researchers are based on various







## > Sustainable Banana Plan

A dialogue platform  
service to help  
producers create and  
select new banana  
varieties

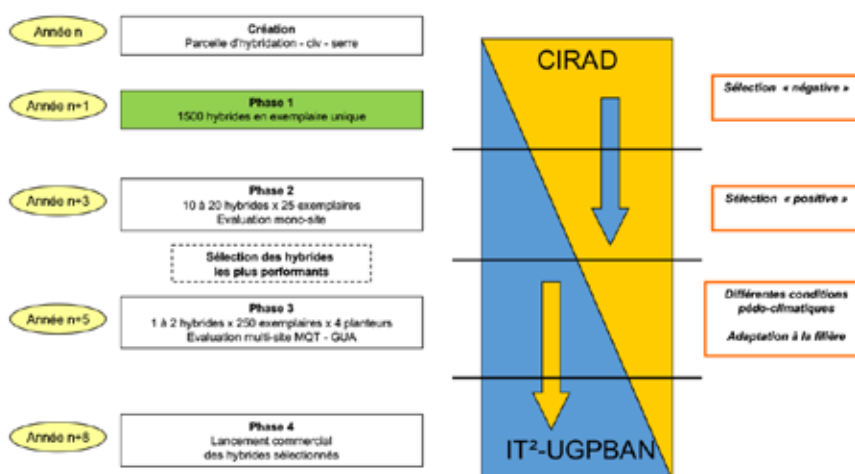
## THE PROFESSION INVOLVED IN THE CHOICE OF VARIETIES

A selection committee was set up when the platform was created. This committee comprises Cirad researchers, varietal development engineers from IT2 and players from across the industry (LPG, Banamart, UGPBAN). It guides and validates the selection choices at each phase transition, and involves the industry at a sufficiently early stage into the innovation process.

Selection committee. © S. Benoit, IT<sup>2</sup>



## Selection schematic





## > CIRAD 925

### A new disease-resistant banana variety, which helps greatly reduce use of pesticides

CIRAD 925 is a new dessert banana variety naturally resistant to several diseases, in particular Sigatoka. Derived from the Cirad varietal creation and selection programme, it is under development and under testing on the markets, in partnership with IT2 and UGPBAN. A slightly acidic, sugary, fairly firm fruit, its taste is as highly rated as the commercial variety Cavendish.

#### A VARIETY RESISTANT TO THE MAIN BANANA DISEASES

Derived from cross-breeding (controlled pollination) of two bananas of the species *Musa acuminata*, this variety has the following assets:

- Partial resistance to black Sigatoka (caused by the fungus *Mycosphaerella fijiensis*) and yellow Sigatoka (*Mycosphaerella musicola*). This resistance inhibits growth of the fungus, and greatly limits its dissemination. Eliminating low leaves, which can exhibit any necroses, will be sufficient to contain development of the disease on a plot of this variety CIRAD 925.
- Resistance to Panama disease Race 1 (*Fusarium oxysporum* f. sp. *cubense*) present in the FWI; though some sensitivity to race TR4 (tested under controlled conditions)
- Good tolerance to the nematodes *Pratylenchus coffeae* and *Radopholus similis*.

Ces These resistance levels help limit use of chemical treatments, thereby contributing to the development of a pesticide-free cropping system.

#### A YIELD POTENTIAL OF 50 TONNES PER HECTARE PER YEAR

A large-sized banana plant (3.9 m) with a short cycle (2 harvests/year) with clusters weighing 20 to 30 kg, the CIRAD 925 variety has a potential yield of approximately 50 tonnes/ha/year. On average, each banana weighs 140 g, measures 19 cm and has a grade of 32 mm.

Various cropping practices have been tested to reduce the height of the plant and increase the weight of the clusters. "Complete" desuckering until flowering and late selection of the offspring sprout are now recommended. Although this practice extends the time between flowering periods, it increases the weight of the fruit by 15%, and reduces the size of the 2<sup>nd</sup> cycle plant by 40 cm. This trial shows that it is possible to correct certain unfavourable traits by adjusting the crop management system.

#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- The CIRAD 925 variety is currently in the industrial development phase. After the upscaling managed by IT2 under conventional management with six pioneer producers, the roll-out of this variety is now heading for a market segmentation strategy.
- Its performance in terms of bioaggressor resistance enable it to be potentially harnessed within an organic agriculture framework. This conversion is currently under testing by Cirad on experimental plots.

#### > INTELLECTUAL PROPERTY

- Variety patent holder: Cirad
- Plant improvement filed for the variety (COV No. 2011/1788)

#### > BACKERS AND CONTRIBUTING PROJECTS

- Sustainable Banana Interreg. Project, Caribbean, 2009-2015
- Sustainable Banana Plan, EAFRD, 2007-2015

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> **CIRAD 925**

A new disease-resistant banana variety, which helps greatly reduce use of pesticides

**GOOD COMMERCIAL QUALITY**

Although it is sensitive to crown rot (mould on the cutting surfaces of the fruit stalk), the CIRAD 925 variety is more tolerant to post-harvest diseases such as ripe-fruit anthracnose (brown stains developing upon maturation of the fruits) than the commercial variety Cavendish. Also, the control of these post-harvest diseases by suitable practices helps ensure a highly satisfactory sanitary state.

Variety CIRAD 925 enjoys numerous qualities. Its fruits remain well attached to their stalk (no "finger drop"), do not get "tiger stripes" (brown stains) and have low sensitivity to bruising. In collaboration with IT2, Cirad has been able to lift some blocking factors which were seemingly unacceptable for fruit exports:

- chilling injury (sensitivity to cold leading to browning), resolved by adjusting the transport temperature to 15 °C,

- split skin, resolved by adjusting the post-gassing relative humidity (perforations in polybags),

- employing flow-packs (plastic sachets with specific permeability) to reduce problems of splitting and improve the visual quality of the fruit,

- and finally the skin-pulp maturation difference was solved by minimising the time interval between arrival in the warehouse and triggering ripening.

Le The only physiological disorder which is still a brake on exports is browning of the skin, when the fruit ripens under low relative humidity conditions during transport. Work is underway to reduce this browning phenomenon and achieve the quality standards of the export banana. ■







## > Banana harvesting

### A prediction system for preventing ripeness on arrival and optimising yield

Cirad has set up a harvest prediction system which enables producers to determine the banana clusters which need to be cut every week. The harvest stage is optimised to prevent early maturation of the bananas during sea-freight shipment to Europe.

**T**he FWI bananas bound for the European market are transported by long-distance sea-freight, and then forwarded by lorry to industrial ripening plants. For the market, the fruits must meet sanitary standards and quality, sizing and maturation characteristics defined by the legislation and distribution sector.

If they ripen during this storage period, which varies in length from 10 to 20 days, the fruits will be downgraded to "ripe on arrival", considered as damaged merchandise, and consequently in most cases destroyed. To determine the optimum banana harvest stage, the producers must find the best compromise between growth (to obtain the best possible yield) and fruit ripeness (to prevent ripening during transport).

Previously, bananas were harvested mainly according to their diameter. Yet in stress situations, the banana plants did not grow quickly, and large-sized fruits harvested were too old and so

kept poorly. Cirad's work has shown that the banana preservation time (green lifetime) depends on the temperature measured between flowering and harvest. In order to meet export conditions, Cirad has developed a harvest prediction system able to optimise the banana cluster harvest date, based on the flowering date (identified on the cluster by a coloured tag) and on the temperature records. ■

Temperature sensor for determining the harvest date. © Luc de Lapeyre, Cirad



#### > TRANSFER STAGE AND DISSEMINATION LEVE

- The implementation of this harvest prediction system in Guadeloupe and Martinique has helped greatly decrease damage due to maturation accidents during transport. The system has been computerised and transferred to producers' groups, producers' groups which now draw up weekly prediction bulletins based on temperature measurements in the various banana production zones. These bulletins are sent out to all banana producers, which use them to determine on a weekly basis which clusters, marked with coloured tags in the field, need to be harvested.

#### > BACKERS AND CONTRIBUTING PROJECTS

- State-Region Plan agreement (1994-1999)
- SPD-FEOGA (2000-2003)
- ERDF (2008-2013)

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## > Post-harvest diseases

# Alternatives to fungicides for treating bananas prior to export

Cirad has developed an alternative method to using fungicides to treat bananas prior to export. This method is based on employing a set of practices in the field and at the packing station.

Marketing the export banana requires careful organisation of the fruit transport and artificial ripening stages, in order to preserve their commercial quality. During these stages, post-harvest diseases such as crown rots (moulds on the stalks) and anthracnose (brown stains on the fruits) may develop and alter the fruit quality. In order to guard against these risks, producers apply fungicidal treatments before exporting the fruit. However, these treatments are not always effective, and generate considerable slurry waste (water contaminated by the fungicides), which needs to be retreated, as well as residue of treatment products in the fruits.

So Cirad has developed an alternative method based on implementing a set of practices in the field and at the packing station:

1 > In the field, where the fruit quality is established, the various processes will determine the fruit contamination level by fungi and the fruit's level of sensitivity to these diseases. This means eliminating inoculum sources in the field, rapidly protecting the bananas with plastic sheaths, and controlling their harvest stage.

2 > In the post-harvest stage, crown rot control requires control of the washing water quality and use of non-perforated plastic bags in the packing boxes. Post-harvest application of a strain of yeast also limits the appearance of the disease.

Finally, Cirad has also developed diagnostic and risk prediction methods which help characterise the risk of appearance of these diseases shortly before the fruit harvest: measuring the banana infestation level by the fungus responsible for the anthracnose (*Colletotrichum musae*) and measuring the sensitivity of the fruit to crown rot and anthracnose. ■



Brushing the floral parts helps eliminate the main sources of fungus spore inoculum.

Crown rot in the ripening plant.



## > TRANSFER STAGE AND DISSEMINATION LEVEL

- Assessment of the integrated management strategy for post-harvest diseases with 3 pioneer producers in Guadeloupe
- Approval of yeast for banana post-harvest applications: in progress in conjunction with IT<sup>2</sup>.

## > BACKERS AND CONTRIBUTING PROJECTS

- State-Region Plan Agreement (1994-1999)
- SPD-EAGF (2000-2003)
- Ministries for Agriculture and Research (Food, Quality, Safety project)

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Banana anthracnose in the ripening plant.







## > Mountain banana

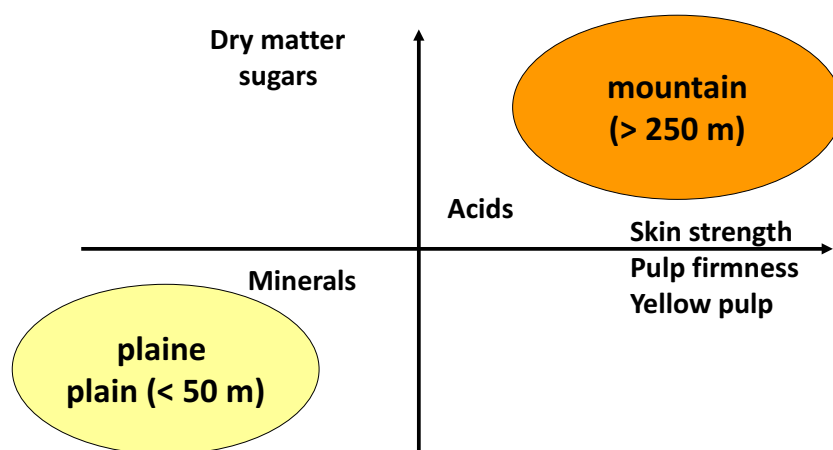
### A new designation scientifically linking quality and production zone

On the strength of the renown and image that symbols of quality represent for consumers, FWI banana producers have opted to identify some of their produce under the designation "mountain banana". In collaboration with the industry, Cirad has verified the links between the product quality and production zone.



**A** firmer banana, with a yellower pulp and more dry matter, more resistant to impacts and post-harvest handling (transport, ripening, display). These are the main characteristics of the mountain banana! These differences from the plain banana are due to the specific climate conditions at altitude (wetter and cooler) and to a longer fruit growth time in the field.

The scientific revelation of the links between the banana and its production zone has helped consolidate the legitimacy of the designation "mountain banana" (obtained in 2006) and reinforce the image that this banana conveys to consumers. The mountain banana is produced above 250 metres in altitude, and meets a set of specifications relating to rational agriculture. ■



#### > TRANSFER STAGE AND DISSEMINATION LEVEL

- Thirty or so producers in the FWI
- 40 000 tonnes already produced in Guadeloupe and Martinique (2005 - 2015)
- A banana awarded "flavour of the year" in 2006 and 2007

#### > BACKERS AND CONTRIBUTING PROJECTS

- Martinique "Rational cultivation" project 2000-2006

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#### > FIND OUT MORE

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