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TA B-26/C – Campus International de Baillarguet - 34398 MONTPELLIER Cedex 5 – France

ANSES - French Agency for Food, Environmental and Occupational Health & Safety
7, chemin de l'Irat 97410 SAINT-PIERRE (Réunion Island)

IN-DEPTH RESEARCH ON MOKO DISEASE

FOOD AND AGRICULTURE INDUSTRIES N.V. (FAI)

SURINAME

17 - 24 MARCH 2022

G. CELLIER – L. de LAPEYRE - T. LESCOT

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1. SERVICE AGREEMENT

BETWEEN

Cirad, ***Centre de Coopération Internationale en Recherche Agronomique pour le Développement***, an *Etablissement Public à caractère Industriel et Commercial* (EPIC), having its registered office located at 42 rue Scheffer, 75116 PARIS, registered in the Paris Trade and Companies Register, under number 331 596 270, and duly represented by Ms. Elisabeth Claverie de Saint Martin, in his capacity as President Director General and by a mandate by Dr. Luc de Lapeyre de Bellaire, Director of GECO Research Unit,

referred to hereinafter as "Cirad",

AND

Food and Agriculture Industries N.V. (FAI), a company incorporated under the laws of the Republic of Suriname, with registered offices at Lakatanweg Br. No. 173, Jarikaba, District of Saramacca, Suriname, registered at the Chamber of Commerce and Industry under number 62307, duly represented by Mrs. Permila Bissumbhar, in her capacity of Managing Director,

hereinafter referred to as “FAI”,

hereinafter referred to individually as the "Party" and collectively as the "Parties",

WHEREAS:

Food and Agriculture Industries N.V. (FAI) is an agricultural company engaged in banana production and export.

Cirad is specialized in conducting useful, targeted research to ensure change and impact on every scale of sustainable development, by means of agricultural and food systems that provide people with healthy food, pay producers a decent wage and are resilient to global change, including climate change, while preserving biodiversity and natural resources.

The research unit GECO - Ecological Functioning and Sustainable Management of Banana and Pineapple is part of CIRAD. GECO conducts functional agro-ecology research and places its expertise at the disposal of the drive to innovate in partnership so as to improve the environmental, economic and social sustainability of banana and pineapple cropping systems.

FAI wishes to entrust to Cirad certain services: carry an expert consultation on Moko disease but also to a less extend about the definition of the new varietal strategy for the coming years and the investigation and advise to develop the exports of FAI bananas and especially to resume exports to Europe.

THE FOLLOWING IS HEREBY AGREED:

PRELIMINARY ARTICLE – DEFINITIONS

Agreement: means this Service Agreement, its Appendices and any amendments.

Confidential information: means all information and/or data, in any form and of any nature whatsoever, shared between the Parties in whatever form, on whatever media and by any means,

designated or deemed to be such during the negotiation and/or performance of the Agreement, relating directly or indirectly to the Service.

Results: means technical and/or scientific information and knowledge and/or any other type of information, whether protected or not, whether it can be protected or not under intellectual property, developed or acquired as part of the Service and arising directly out of work carried out in the context of the Agreement.

Know-how: means technical knowledge or skill, whether transferable or not, that is not immediately accessible to the general public.

ARTICLE 1 – PURPOSE

The purpose of this Agreement is to define the conditions under which FAI will entrust to Cirad the provision of the following service:

In-depth Research on Moko Disease at Food and Agriculture Industries NV

The detailed schedule of said work (hereinafter the "Service") is included in the Technical Appendix attached.

ARTICLE 2 – DURATION

Notwithstanding its date of signature, the Agreement takes effect on the date of signature for a period of three months.

The field assessment will be conducted in March 2022.

It may be extended at the end of said period by an amendment that will state the purpose of the extension, its duration, and the terms of its funding.

The expiry or termination of the Agreement shall not affect the stipulations of the Articles "Confidentiality and Publication", "Ownership of Results" and "Non-solicitation of staff" which shall remain in force for the periods established in said Articles.

ARTICLE 3 – COORDINATION AND MONITORING

Those responsible for monitoring the Agreement are:

- for Cirad: Mr. Thierry LESCOT, agronomist specialized in banana and plantain production
- for FAI: Mrs. Shiewa NANHOE, Director of Agronomics & Research

The Parties will keep each other informed of any change in contact person.

A final summary report will be drawn up by Cirad in the months prior to the date of expiry (approximately the or early termination of the Agreement.

The final report will be submitted in duplicate – two original and confidential copies – forming a summary of work carried out and describing the Results obtained in the wake of the Service and an electronic copy will be submitted to FAI.

ARTICLE 4 – SERVICE PROVISION PROCEDURES

4.1. Cirad undertakes to provide the Service in accordance with the technical procedures described in the Technical Appendix.

4.2. Regarding performance of the Agreement, the Parties designate address for service at their registered offices as indicated at the head of this document.

4.3. Cirad reserves the option to implement its Know-how in the provision of similar services on behalf of third parties.

ARTICLE 5 – FUNDING PROCEDURES

5.1 Contributions

As consideration for the undertakings entered into by Cirad under the Agreement, FAI undertakes to pay it the following sum:

- Amount excluding taxes: 38 516 Euros

Any additional services not included in the purpose of the Agreement may only be performed on condition that the Parties come to a specific prior written agreement both on the nature and the price of the service envisaged.

5.2. Instalments

Payment will be made by FAI in the following instalments:

- 23.109,60€ (60% of the total budget) upon signature hereof;

- 11.554,80€ (30% of the total budget) at the end of the field working days;

- 3.851,60€ (10% of the total budget) forming the balance, upon acceptance by the Management Team FAI of the Final Report.

5.3. Payment procedures

The sums due will be paid by FAI into Cirad's account, upon submission of duly issued invoices.

Bank name: BNP PARIBAS ETOILE
Bank account holder's name: CIRAD-PERSYST
Account currency: Euro
RIB: FR76 3000 4008 9200 0104 4361 521
Duly issued invoices are to be sent to FAI Finance Department for the attention of Mr. Aniel KEWAL (akewal@fai.sr) and Mrs. Ashwani DOERGA (adoerga@fai.sr).

5.4 Late payment penalties

Any delay in payment in relation to the conditions fixed between the Parties will result in the payment by FAI of the sum of forty (40) Euros for recovery costs as well as late payment penalties, according to the legal and regulatory provisions applicable to FAI, at the rate of interest applied by the European Central Bank in force increased by ten (10) percentage points, in accordance with articles L441-6 and D.441-5 of the French Commercial Code.

ARTICLE 6 – CONFIDENTIALITY AND PUBLICATION

6.1. Each Party undertakes not to publish or disclose in any way whatsoever Confidential Information belonging to the other Party. Said undertaking will remain in force for five (5) years after the expiry or termination of the Agreement.

The Parties will no longer be bound by the undertakings in this Article 6.1 if they can prove that the Confidential Information:

- was publicly available prior to its disclosure or after said disclosure in the absence of any misconduct attributable to them;

- has been received from a third party in a lawful manner;

- was already in their possession before the Agreement was concluded;

- was developed independently and in good faith by members of their staff that did not have access to the Confidential Information;

- was disclosed by virtue of a Court decision;

- was disclosed by the Party having produced it:

- was used or disclosed with the written authorization of the Party to which it relates.

6.2. The Parties undertake to communicate the Confidential Information only to members of their staff [or their subcontractors] needing access thereto in order to provide the Service. The Parties undertake to ensure that any of their staff having been communicated the Confidential Information will comply with these provisions.

The Parties undertakes in particular to use the Confidential Information and the Results for the sole purposes of providing the Service, except where expressly authorized beforehand by the other Party in writing.

6.3. However, the provisions of this Article may not stand in the way of the obligation incumbent upon each of the persons participating in the Service to submit a work report to their organization, since such communication does not constitute disclosure within the meaning of intellectual property legislation.

6.4. Any communication or publication by FAI relating to the Results must indicate that said Results were obtained by Cirad. FAI must not under any circumstances disclose the Know-how implemented by Cirad without prior written authorization.

ARTICLE 7 – OWNERSHIP OF RESULTS

7.1. The Results obtained from the Service will be fully owned by FAI, that will hold all rights to the aforementioned Results, and may protect them under any intellectual property rights. FAI will pay all costs thereof and retain any and all profits that might thereby arise.

By express agreement, FAI acquires ownership of the Results of the Service, upon receipt of full payment for the Service by Cirad.

7.2. Know-how and any knowledge prior to this Agreement belonging to and implemented by Cirad in order to provide the Service shall remain its property, as will any improvements in the Know-how acquired in providing the Service.

7.3. Cirad may use the Results of the Service freely and free of charge for its own research purposes, at their own risk and responsibility.

ARTICLE 8 – OBLIGATION OF COLLABORATION

FAI will make available to Cirad all information, materials/equipment and staff necessary to the smooth running of the Service. To this end, the contact persons designated in the Article "Coordination and Monitoring" of the Agreement will enter into a dialogue at the various stages in the provision of the Service.

FAI will also be responsible for the safety of Cirad experts as well as their local travel, accommodation and subsistence.

ARTICLE 9 – OBLIGATION OF ACCEPTANCE

Upon receipt of the final report submitted to FAI for approval, the latter will have a period of 2 weeks to inform Cirad of their observations and proposals for corrections, so that the final payment of the Service can be executed.

ARTICLE 10 – GUARANTEE

The Parties recognize that the Results or any other Confidential Information communicated by one Party to the other Party in performance of this Agreement will be communicated as is, without any guarantees of any sort.

The following are expressly excluded: any guarantees relating to commercial and/or industrial exploitation of the Results, their safety, or their compatibility or compliance with a specific use, freedom from error or defects or dependency on third-party rights.

Such Results and Confidential Information are used by the Parties under the Agreement at their respective sole cost and risk and, therefore, neither Party may have recourse against another Party, or any of their subcontractors, or their staff, for any reason whatsoever and in any respect whatsoever, as a result of the use of such Results and Confidential Information.

ARTICLE 11 – LIABILITY

“Cirad is not liable for indirect damage or damage that is not the direct result of an act and/or inaction, partially or not partially, of Cirad in the performance of this agreement, such as, but not limited to, loss of data, interference with business, loss of profit.

In the event of damage suffered by FAI, an independent investigation committee appointed by a party will investigate to what extent the damage is the direct result of an act and/or failure to act, partially or not partially, by Cirad in the execution of this agreement.

If the aforementioned investigation committee has concluded that the damage is the direct result of an act and/or failure to act, partially or not partially, by Cirad in the execution of this agreement, this damage must be fully compensated by Cirad, as well as the costs of the investigation carried out by the Commission of Inquiry.

Otherwise, the costs of the investigation conducted by the Commission of Inquiry will be borne by FAI.”

In any case, if the Cirad's liability were incurred under this Agreement, the amount of compensation that it might be obliged to pay shall not under any circumstances exceed the total amount of payments then made by FAI in consideration for the Services provided, all prejudice and grounds included.

ARTICLE 12 – TERMINATION

12.1. If there is a change in the economic, political or social context leading to an imbalance in the Agreement or difficulties likely to call into question performance of the Agreement, the Parties undertake to inform each other by letter or e-mail (with acknowledgement of receipt) and will make every effort to perform their contractual obligations. If it is impossible for one Party to perform their contractual obligations as a result of such new context, the Parties will meet to take into account the new context of the relationship between the Parties and will, if appropriate, amend the Agreement if the situation obliges them to do so.

12.2. However, the Agreement may be terminated by one of the Parties in the event of serious or repeated non-performance by the other Party of one or more of the substantial obligations contained in its various clauses. Such termination will only become effective three (3) months after the sending by the complainant Party of a registered letter with request for return receipt setting out the reasons for the complaint, unless, within said period, the defaulting Party has fulfilled their obligations or provided the proof of a hindrance following an event of force majeure.

The exercising of this termination option does not release the defaulting Party from fulfilling the obligations entered into up to the date of effect of the termination, subject to any damages suffered by the complainant Party as a result of the early termination of the Agreement.

12.3. The Agreement will also be terminated if the activities of FAI are closed down, wound up or in the event of bankruptcy.

ARTICLE 13 – RESTITUTION

Upon expiry or termination of the Agreement, the Parties undertake to return, within thirty (30) days, all media containing Confidential Information as well as documents or materials received from the other Party in performance of the Agreement. Moreover, the Parties undertake not to retain any copy of Confidential Information on any media whatsoever and to delete from any processing systems or data storage systems any Confidential Information that might have been included therein, and to provide the other Party with proof thereof upon first request.

ARTICLE 14 – FORCE MAJEURE

14.1. In the event of a case of force majeure, obligations resulting from the Contract, whose performance has become impossible, shall be suspended as long as this impossibility lasts. The defaulting Party shall not be held liable for such non-performance, nor shall the other Party be entitled to claim damages or penalties for late payment.

14.2.1 Force majeure shall be considered as any event preventing one of the Parties from performing its obligation and satisfying the following cumulative conditions:

(a) An event beyond its control;

(b) An event reasonably unforeseeable at the time of the conclusion of the Contract;

(c) An event whose effects cannot be avoided by appropriate means;

14.2.2. In particular, the following events shall be considered as cases of force majeure, without the defaulting Party having to establish that such event presents the characteristics defined in (a) and (b) of the previous paragraph: strikes, border shutdown, containment and quarantine measures, wars, riots, terrorist acts, fires and natural disasters.

14.2.3. Events caused by the negligence or wilful act of one of the Parties or its subcontractors, agents, employees, or by non-compliance with professional practices shall not be considered as force majeure cases.

14.3. The defaulting Party shall notify the other Party without delay of the occurrence of such case of force majeure by registered letter with acknowledgement of receipt, specifying its nature and the foreseeable duration of the impediment. The same Party shall also notify the other Party without delay of the cessation of the impediment.

14.4. If the impediment is definitive, the Contract may be terminated by one of the Parties by registered letter with acknowledgement of receipt, without giving rise to the payment of damages.

14.5. If termination is not requested, the obligations affected by the force majeure event are automatically extended by a period of time equal to the delay it caused. No party shall be liable for non-performance of their obligations if and insofar as said non-performance is due to an event of force majeure, as defined by French case law.

ARTICLE 16 – SUBCONTRACTORS

Cirad is authorized to subcontract all or part of the Service.

ARTICLE 17 – NON-SOLICITATION OF PERSONNEL

FAI undertakes not to hire, attempt to hire or put to work in any way, any present or future employee of Cirad, whatever the specialization of the employee in question, even if the solicitation were at the initiative of said employee.

This clause shall produce its effects throughout the period of performance of the Agreement, and for two (2) years as from its expiry or early termination.

ARTICLE 18 – INVALIDITY OF A CLAUSE

The nullity of one or more stipulations of the Agreement shall not lead to the annulment of the whole Agreement, except where the nullity of said stipulation makes the Agreement incompatible with the Parties' intention on the day of its signature.

If one of these clauses should be annulled, the Agreement will be pursued in the absence of the annulled provision. If it is necessary to performance of the Agreement, the Parties will meet as soon as possible to negotiate in good faith a new clause to replace the annulled clause, by means of an amendment, making every effort to observe the Parties' joint intention as it existed on the day of signature of the Agreement.

ARTICLE 19 – IMMUTABILITY

The fact that either Party does not exercise any of the rights that they hold under the Agreement shall not under any circumstances constitute a waiver of such exercising on their part, and said waiver may only result from an express statement by the Party concerned.

ARTICLE 20 – APPLICABLE LAW

This Agreement is subject to French laws and regulations.

ARTICLE 21 – DISPUTES

In the event of a dispute relating to the validity, interpretation, performance, or termination of the Agreement, the Parties undertake, prior to any other recourse, to make their best efforts to find an amicable solution.

If the disagreement subsists, the case will be brought before the competent Courts.

In 2 copies

CIRAD	**FAI**
Name: Luc de Lapeyre de Bellaire	**Name:** Permila Bissumbhar
Position: GECO Research Unit Manager	**Position:** Managing Director
Date: __14/02/2022_____	**Date: __11 feb 2022_____**
Signature: _____	**Signature: _____**

TECHNICAL APPENDIX

1. DESCRIPTION OF THE CONSULTANCY

Epidemiological surveillance of plant pathogens is of great importance for integrated plant protection. Tracing of bacterial strains and identification of emerging clones escaping control strategies requires extremely precise strain identification. The *Ralstonia solanacearum* species complex (RSSC) provides unique models for studying plant-pathogen interactions, including basic biology of pathogenesis and non-host resistance in the context of an unusually broad host range and latent (asymptomatic) infection. This organism is a high-impact pathogen of economically important cash and industrial crops like banana, tomato, potato, and ornamentals. Moreover, it is spreading globally and adapting to new hosts. RSSC strains are described as quarantine pathogens of dual use in Europe (civil and military), and considered as bioterrorism select agents in USA. Its high-risk status makes it a priority for any territory to prevent introduction, dissemination, and establishment via imported plant material.

This proposed research will examine bacterial strain occurring as an epidemiologically active bacterial wilt agent in Suriname, and gather our collective expertise on both the banana genomic resources and the complex genetic diversity of the RSSC. To achieve these objectives, several actions are planned: (i) field surveys in two locations (Jarikaba & Nickerie); (ii) molecular identification and characterization the isolated strains; (iii) Evaluate banana genetic resources and cultural practices to overcome bacterial wilt; (iv) organization of a training session for knowledge sharing.

2. EXPERTS

The consultancy will be led by four experts :

- **Expert 1 / Gilles Cellier** : Phytopathologist, Project coordinator in microbiology and molecular biology for tropical pathogens at ANSES (Official French Agency for Food, Environmental and Occupational Health & Safety) ; specialist of Moko disease (*Ralstonia solanacearum*)

- **Expert 2 / Luc de Lapeyre de Bellaire** : Phytopathologist, CIRAD, Head of the Research Unit " Ecological functioning and sustainable management of banana, plantain & pineapple agrosystems" ; specialist of banana diseases

- **Expert 3 / Denis Loeillet** : Agro-economist, CIRAD, Correspondent for the bananas and plantains sector, Director of the Tropical Fruit Market Observatory, and of the review 'FruiTrop' ; specialist of international banana trade

- **Expert 4 / Thierry Lescot** : Agronomist, CIRAD ; specialist of banana & plantain productions

3. DESCRIPTION OF THE APPROACH

The consultancy will follow different steps :

a. Meetings with FAI managers: inventory (including export), rehabilitation project for the two production sites, possibility of an extension project on a new site, need for technical assistance, etc. (4 experts)
b. Visits of the different plots of the 2 sites (2-3 days, 4 experts) ; sampling taking (Gilles Cellier, Luc de Lapeyre)
c. Analysis of laboratory facilities (Gilles Cellier)

d. Laboratory isolation, culture and analysis (including training of FAI personnel) (Gilles Cellier, Luc de Lapeyre)
e. Performance analysis of current varieties (Thierry Lescot)
f. Proposal for the evaluation of the 'Ruby' variety (tolerant to TR4), Vitropic in association with Grassalco lab (Thierry Lescot)
g. Proposal for the evaluation of 3 hybrid varieties (AAA triploids) from CIRAD, resistant to TR4, Vitropic in association with Grassalco lab (Thierry Lescot)
h. Analysis of the different technical itineraries from the soil preparation to harvest & packing station (Thierry Lescot, Luc de Lapeyre)
i. Presentation of the current situation of the international market with special focus on the EU (Denis Loeillet)
j. Opportunities for Suriname (Denis Loeillet)
k. Debriefing (short report)
l. Full report submission (one week after mission)

4. Indicative timetable of activities

	Week 1				Week 2
Activities					
Meetings with FAI managers					
Visits of the different plots of the 2 sites					
Analysis, proposals and training of FAI staff					
Debriefing at the end of the mission					
Deliverable					
Final report					

The expertise will be carried-out on the 2 spots (Jarikaba & Nickerie) for six days. Three working days will be devoted for reporting. A presentation will be made to FAI staff at the end of the assessment period.

2. THE MOKO DISEASE: STATE OF THE ART

2.1. CLASSIFICATION OF THE RSSC

Soil-borne plant diseases caused by bacteria are one of the most difficult diseases to manage, relatively to the particular lifestyle of the pathogen and scarcity of management methods. Effective measure is mostly based on prevention (epidemiological surveillance, elimination of inoculum sources), associated with rational deployment of resistant varieties. Therefore, in order to develop relevant control strategies, knowing the genetic and phenotypic diversity of pathogens, along with dynamic structure of their populations, appears as preponderant. Further disease risk assessment study need to focus on the evolutionary forces leading to new pathogenic variant and outbreaks, through evaluation of migration routes / dissemination at local, regional, and global levels; and estimate their ability to bypass plant resistance or to spread into the environment.

Strains from the *Ralstonia solanacearum* species complex (RSSC) are causal agent of bacterial wilt that can be found on more than 200 host species (Hayward, 1994). Bacterial wilt is considered as one of the most damaging plant bacterial disease worldwide (Mansfield et al., 2012). This ancient soil-borne and vascular bacterial disease also emerged in temperate zones (Europe, USA) during the last 20 years and is still considered as a major biotic constraint for vegetable crops (tomato, potato, eggplant, pepper...), fruit (banana), ornamentals (*Pelargonium*, *Anthurium*, *Pothos*...), and forest (teak, eucalyptus...) in tropical and subtropical areas. Given its geographical distribution, its host range in continuous extension and its economic impact, it is considered as quarantine bacterium in Europe (Directive 2000/29/EC, EPPO A2 list) and is listed as "Bioterrorism Select Agent" in the United States.

RSSC is regarded as a species complex (Gillings and Fahy, 1994) composed of four Phylotypes correlated with geographical origin of the strains: Asia for the Phylotype I; America for the Phylotype II (A and B); Africa for the Phylotype III; Indonesia, Australia, and Japan for the Phylotype IV (Fegan and Prior, 2005). Recently, this species complex have been delineated into three distinct species (Safni et al., 2014; Prior et al., 2016), namely *Ralstonia solanacearum* (Phylotype II); *Ralstonia pseudosolanacearum* (Phylotypes I and III); and *Ralstonia syzygii* (Phylotype IV). Sequevars are a working definition, based on sequence variation of the endoglucanase gene (*egl*); and constitute unique subdivisions of Phylotypes.

Despite many efforts to diversify strategies by using alternative methods (biological control, service plants, natural stimulators of plant defense, plant coverage against bacterial wilt), genetic control remains the strategy of choice and the most promising and reliable method. Sadly, development of sustainable and universal resistance sources against bacterial wilt encountered many difficulties due to:

(i) Essentially quantitative and partial nature of known resistance, with a strong genotype versus environment interaction;

(ii) Lack of information of the genetic diversity and phenotypic strains used in breeding programs;

(iii) Local fluctuations in time of RSSC strain populations, mainly due to the high phenotypic and genotypic plasticity of the bacterium.

2.2. THE MOKO DISEASE AND RELATED RSSC BANANA STRAINS

The description for Moko was done at the beginning of the last century by Rorer (1911) during an outbreak in Trinidad on plantations of the susceptible cultivar 'Moko' (Musa ABB, Bluggoe subgroup) from which the common name of the disease was adopted. Until the early 1950s, commercial plantations remained free of the disease, but since 1950 three consecutive bacterial wilt epidemics swept through Central and South America, and is now considered as endemic (Lehmann-Danzinger, 1987). Around the world, Moko is considered a threatening disease to bananas and plantains, together with black sigatoka (*Mycosphaerella fijiensis*) (Lehmann-Danzinger, 1987; Sequeira, 1998).

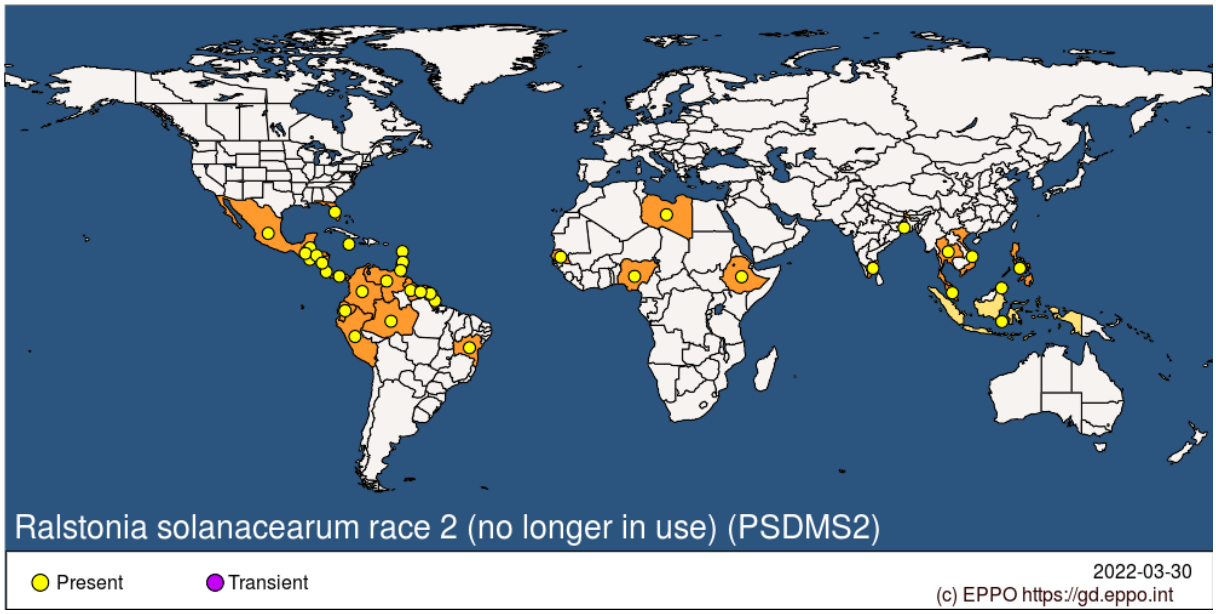


Figure 1 - Distribution map of the Moko Disease

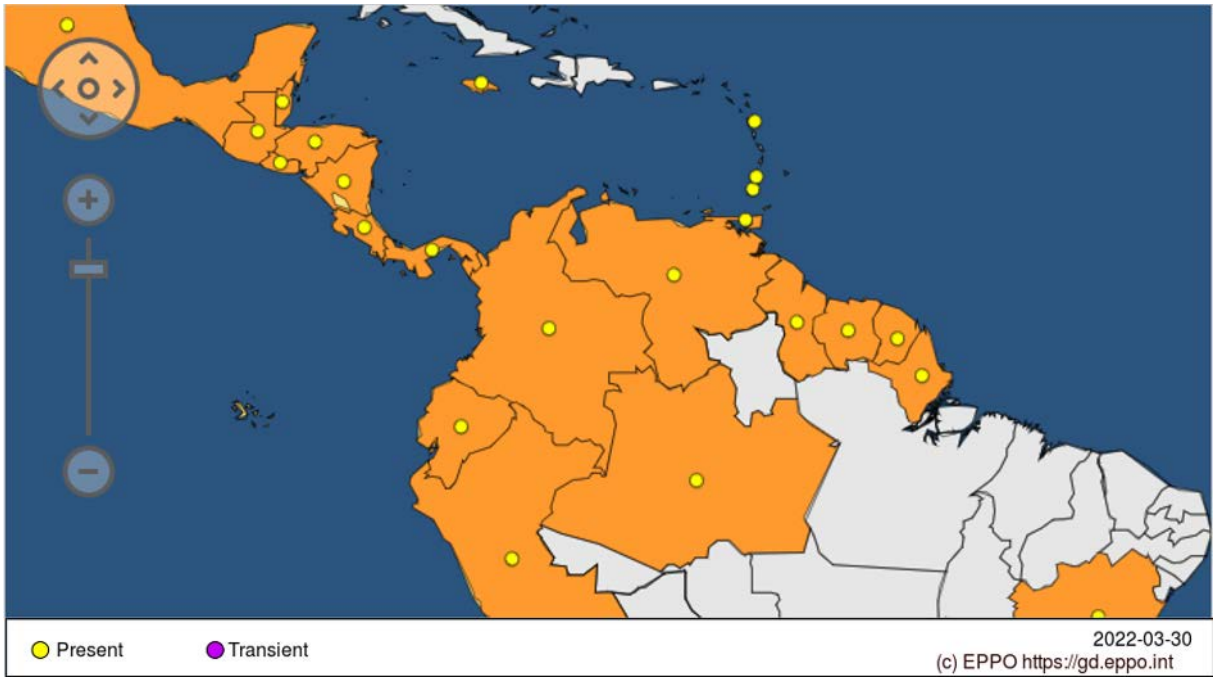


Figure 2 - Distribution map of the Moko disease – Focus on Suriname

Ralstonia solanacearum strains affecting *Musa* spp. are defined by symptom expression in the plant, microbiological cultural characteristics, or modality of spread (mostly through insects or by mechanical/soil transmission) (French, 1985; Sequeira, 1998):

- **SFR** (Small, Fluidal, and Round) strain forms small, fluidal, and round colonies; mainly transmitted by insect; highly pathogenic.
  Phylotype IIB-4 or IIA-6
  [Central America, Venezuela, Columbia, Caribbean]
- **A** (Amazon basin) strain forms near round colonies; mainly transmitted by insect; highly pathogenic
  Phylotype IIB-4
  [Peru]
- **B** (Banana) strain forms large elliptical colonies; mainly transmitted through root contact and contaminated planting equipment (soil borne); few oozing through flowers; highly pathogenic.
  Phylotype IIB-3
  [Central and South America, The Philippines]
- **D** (Distortion) strain forms large elliptical colonies; low pathogenicity for banana plantain, and Heliconia.
  Phylotype IIB-3 or IIB-4
  [Costa Rica, Surinam, Guyana]
- **H** (Heliconia) strain forms large elliptical colonies; pathogenic for plantain, but not banana
  Phylotype IIB-3
  [Costa Rica]
- **R** strain forms large elliptical colonies, lacelike slime; slight formazan pigmentation towards center; Stunting and distortion of *Heliconia* only.
  Phylotype: unknown
  [Costa Rica]
- Phylogenetic analysis of the *egl* sequences has revealed a fourth genetic group of strains causing Moko disease from banana in Brazil (Das et al., 2006).
  Phylotype IIA-24
  [*Brazil*]
- More recently, other Sequevars were discovered to harbor Moko strains along with other non-Moko strains (*Solanaceae* only) (Albuquerque et al., 2014).
  Phylotype IIA-41, IIA-53, and IIB-25
  [*Brazil*]

The name “Bugtok” is used when wilt symptoms, caused by *R. solanacearum* Phylotype IIB-3 strains, appear on ABB cooking type bananas in the Philippines (Molina, 1999; 2006), and was first reported in Mindanao region in the early 1950s (Soguilon et al., 1994). In this country, insect transmission is very rare in Cavendish because bunches are bagged with plastic at the time of shooting to prevent insect damage and possible insect-mediated disease transmission (Stover and Simmonds, 1987). The similarity bet ween Philippines Bugtok and Moko disease causing strains extends to the pathogenicity of strains which is indistinguishable when strains are inoculated onto Dwarf Cavendish and Saba plantlets (Ilagan et al., 2003).

The polyphyletic nature of the *R. solanacearum* (Phylotype II) strains causing the Moko disease remains to be elucidated.it is likely that Moko disease in the Philippines was the result of a single introduction of a strain of Phylotype IIB-3 from South America . In contrast, it has been suggested

that certain Moko strains may have originated in Southeast Asia (Eden-Green, 1994b) but this seems unlikely. The greatest genetic diversity of strains causing Moko disease is found in strains from South America where it probably evolved associated with wild *Heliconia* species (Thwaites et al., 2000). It is generally accepted that genetic diversity of a pathogen is usually greatest in the center of origin. Also, Phylotype IIB-3 strains are closely related to Phylotype IIB-4 strains indicating an evolutionary link between these groups of strains. Phylotype IIB-4 strains are only found in South America. It is therefore likely that a single genotype (Phylotype IIB-3) of the pathogen was moved to the Philippines on infected banana plants as has been previously suggested (Buddenhagen, 1985).

Common name	Distribution and hosts	Traditional taxonomy	Currently accepted taxonomy	Proposed species
Moko	America (Mexico), Venezuela, Guyana, Colombia, Peru; Brazil; Caribbean (Grenada, Dominican Republic and Jamaica) ; Malaysia ; Philippines (AAA types; "Moko")	*Ralstonia solanacearum* biovar 1, race 2	IIA-6, IIA-24, IIA-41, IIA-53, IIB-3, IIB-4, and IIB-25	*Ralstonia solanacearum*
Bugtok, Tibaglon, Tapurok	Philippines (ABB/BBB types; "Bugtok")		IIB-3	

Table 1 – Relationship between Moko and Bugtok disease from Blomme et al. (2017).

In recent literature, it has been suggested that pathogenicity to banana lies in a very restricted number of genes (or even allelic forms of the same genes) that may be easily transferable through horizontal gene transfer (Wicker et al., 2012). Although elegant, this assumption was not supported by recent comparative genomic work (Ailloud et al., 2015). The robustness of the Phylotype classification, thus far, would imply that it reflects true evolutionary lineages within the RSSC (Blomme et al., 2017). These lineages presumably developed when progenitors became geographically isolated and subsequently adapted to different environments and potential host plants (Denny, 2006).

Blood disease bacterium (BDB) strains, which cause blood disease of banana, belong to the Phylotype IV of the RSSC and the *Ralstonia syzygii* species (Safni et al., 2014), that has been divided into three subspecies:

- The clove (*Syzygium aromaticum*) pathogenic strains as *Ralstonia syzygii* subsp. s*yzygii* ;
- The *Solanaceae* pathogenic strains as *Ralstonia syzygii* subsp. *indonesiensis* ;
- The Banana blood disease bacterium strains as *Ralstonia syzygii* subsp. *celebesensis*.

Banana blood disease is thought to have originated on Salayar Island near Sulawesi, where it was first reported after the introduction of dessert bananas in the early 1900s (Eden-Green, 1994a; Thwaites et al., 2000). It had become widespread on local cooking banana cultivars in southern Sulawesi (formerly Celebes) by 1920 (Gäumann, 1921; Stover and Espinoza, 1992), and then probably spread throughout the island until its discovery in Java in the late 1980s (Thwaites et al., 2000). No BDB strains are known to cause disease of *Solanaceae* (Eden-Green, 1994a), and are typed as Phylotype IV-8 and IV-9.

2.3. SYMPTOMATOLOGY

Symptomatology has commonalities, between Moko strains and other strains from the RSSC: pathogenic cells enter host plants via wounds that expose internal tissues (Blomme et al., 2017). Such wounds may be either artificial or naturally appearing during plant development (Blomme et al., 2017). Management practices using garden tools such as machetes may also create entry sites for bacteria (Ocimati et al., 2013). In addition, nematodes may cause wounds enabling root entry (Denny et al., 2006).

The specificity of Banana wilting RSSC strains, including Moko and BDB, is the ability to invade banana flowers. The abscission of male flowers creates a moist site with open xylem vessels that can be inoculated by bees or other flying insects that carry the pathogen from diseased plants that are oozing bacteria on infected inflorescences (Buddenhagen and Kelman, 1964). Through these means, the disease can progress over long distance: BDB progression has been shown to occur at over 25 km per annum in some areas of Indonesia on cooking and dessert bananas (Eden-Green and Seal, 1993).

Typical Moko wilt symptoms appear once the pathogen has systemically colonized the pseudostem and underground rhizome (Blomme et al., 2017). Infected dessert banana plants exhibit rapid yellowing and wilting of leaves and physically attached suckers, vascular discoloration in the pseudostem leaf sheaths, premature fruit ripening or arrested fruit development and fruit blackening, and dry rot of fruit pulp (Thwaites et al., 2000; Denny, 2006). Bacterial ooze can be readily observed in internal tissues of any part of the plant that becomes exposed to the air. In certain conditions internal pseudostem discoloration caused by Moko strains can be confused with Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*) and in loco diagnosis needs to be done by experts (Blomme et al., 2017). The inspection of bunches to observe rotting fruits, the presence of young distorted rotting suckers and bacterial oozing from exposed tissues is a common practice to discriminate between Moko disease and Fusarium wilt as rotting fruit and bacterial ooze do not appear in plants with Fusarium wilt (Blomme et al., 2017).

2.4. DISSEMINATION AND DISPERSION

Contaminated farm machinery, garden tools and machetes used for pruning and de-suckering, and infected fruit and rhizomes (used as planting material) are also effective vehicles of dissemination (Ploetz et al., 2015). Contaminated water reservoirs (for irrigation purposes) are extremely effective to disseminate RSSC strains (Elphinstone, 1998; Wenneker et al., 1999; van Elsas et al., 2001; Alvarez et al., 2008) and are major constraints to control Moko in Latin America (Blomme et al., 2017). Often the survival of RSSC strains in water or in the environment is ensure by the wild compartment (weeds), that can harbor high concentration without showing any symptoms (Berg, 1971; Moffett and Hayward, 1980; Dittapongpitch and Surat, 2003). This particularity makes the eradication of RSSC strains almost impossible in a contaminated landscape (Elphinstone, 1998; Janse et al., 1998).

Soil-related dispersions play a significant role for most of RSSC strains, but for the Moko disease, Insect transmission is far more effective (Molina, 1999; Biruma et al., 2007). According to the pathogenic agent responsible of the infection, different ways of dissemination have to be carefully considered. For instance, B strains (Phylotype IIB-3) are mainly soil-borne and transmitted by root-to-root contact and farm management practices such as pruning (Bautista-Montealegre et al., 2016). Insects may transmit B strains, but this is, however, rare, as plants infected by B strains exude relatively little bacterial ooze (Blomme et al., 2017). By contrast, SFR (Phylotype IIB-4 or IIA-6) and A (Phylotype IIB-4) strains are readily insect-transmitted (Buddenhagen and Kelman, 1964). Trigona bees, wasps, and other insects have been reported to disseminate the SFR and, to a lesser extent, B strains (Stover, 1972; Buddenhagen, 1994; Ploetz et al., 2015; Jones, 2018). Generalist insects and stingless bees, such as Trigona spp., feed on the nectar-like sap of banana plants, which exudes from fresh cushions where male flowers have fallen from their point of attachment (Blomme et al., 2017).

On blood disease infected plants, bacteria-filled droplets begin to ooze from such cushions about 15–25 days after infection (Blomme et al., 2017). Although insects frequent both male and female flowers, these fresh cushions are the only surfaces containing open xylem vessels and nectar-like sap. The infection court (i.e., site in or on a host plant where infection can occur) is therefore not the flowers themselves, and only rarely the bract scars (Buddenhagen, 2009).

RSSC strains has been reported to survive in agricultural soil up to 1 year even after eliminating host plants using herbicide (van Elsas et al., 2005). Observations of wilting of tomato have been recorded after more than 10 years of sugarcane (non-RSSC host) (Cellier, personal communication).

Latently infected planting materials are known to promote long-distance dispersal of bacterial wilt pathogens (Molina, 2006). For example, the dispersion of Moko from Central America to the Philippines has been attributed to infected suckers (Rillo, 1979; Buddenhagen, 1985). In Indonesia, the movement of blood disease can also be traced with movements of planting materials and infected plant parts especially the balbisianas (ABB and BBB) since these are important cooking bananas and are used in socio-cultural events (Blomme et al., 2017).

Agricultural practices such as the use of cableways to transport bunches and tools from the plantations to packinghouses may be important for bacterial dispersion (Blomme et al., 2017). Munar-Vivas et al. (2010) used field-integrated information in geographical information system (GIS)-based maps to evaluate the presence of Moko in the Urabá region of Colombia, during three different time periods. They showed that 76% of Moko detected during the three time periods was associated with cableways used for transporting fruits and field consumables.

Disease progression is largely dependent on host susceptibility, environmental factors, existence of contaminated water sources and management practices. Incubation periods may vary depending on the maturity of the infected plant, method of inoculation, route of infection, and environmental conditions.

2.5. Survival of Moko strains and vertisol management

RSSC strains are well fitted to survive in most environments and for decades without any compatible hosts. By comparing oxisols and vertisols, Prior et al. (1993) concluded that ferralitic or recent clay soils (alluvial, volcanic) composed of a kaolinite or halloysite type sheet ($5 < pH < 7$) are the most easily contaminated by RSSC strains because they are very receptive : RSSC strains persist and circulate there indefinitely. On the contrary, vertisols have a suppressive action, which is linked to the presence of montmorillonite, a smectite-type clay. These smectite-type clay soils form a network of tactoids shaping a honeycomb-like structure that captures bacteria from the soil, which are no longer available to infect the roots, including RSSC strains. Wet and dry fallow rotations are mandatory to reduce RSSC populations in the soil.

When water-saturated, the vertisol is destructured and releases into the environment the previously captive bacteria. Soil moisture affects the persistence of the pathogen, which tends to survive better in moist soil, but RSSC strains growth is inhibited in flooded or desiccated soil (Moffett et al., 1981; Hayward, 1991). While drying, the suction of the soil makes the tactoids network loose and homogeneous, and if dried out to a certain amount (beyond pF[1] 4), desiccation causes compaction of the tactoids network, which decreases in porosity and can mechanically crush the bacteria under

[1] pF is the decimal logarithm of the suction expressed in centimeters (head) of water.

high pressure. Bacteria cells are hence exploding, resulting in a significate decrease of bacterium inoculum pressure (Prior et al., 1993).

2.6. GENERAL INFO ON CONTROL METHODS

Key factors for management success are systematic and disciplined adoption and execution of monitoring and eradication of infected plants (Blomme et al., 2017).

The success of control strategies strongly relies on capacity building, systematic eradication, and sanitation activities. Hence, the adoption of biosafety practices at the farm and landscape level is considered as the most critical factor to manage bacterial wilts in banana. Differences in inflorescence morphology across cultivars results in varying degrees of susceptibility to insect-mediated infection (Blomme et al., 2017). Host-pathogen interaction and the importance of cultivar susceptibility and management practices on symptom development are illustrated by Bugtok in the Philippines and the B strain of Moko from Honduras (Molina, 1999).

2.6.1. Diagnostic

As a first critical step in Moko disease management, disease recognition should be achieved by plant-by-plant inspection at regular intervals (Blomme et al., 2017). Available data on the average incubation period suggest that inspections need to be done at weekly intervals (Lehmann-Danzinger, 1987). The earliest appearance of Moko symptoms is two weeks after infection (Lehmann-Danzinger, 1987). Early Moko scouting is mainly based on early symptoms of wilting and chlorosis on un-shot plants; and there are hence as good as no sources of inoculum for insect transmission (Blomme et al., 2017).

2.6.2. Cultural Control

2.6.2.1. Generalities

Use of clean planting material and good sanitation procedures need to be always coupled to quarantine methods (Blomme et al., 2014; Blomme et al., 2017).

Within a Moko infected area, control options should focus on a systematic area-wide approach, with the adoption of a combination of activities (Blomme et al., 2017), such as:

- Limitation of access of animals, workers/laborers and equipment from and to the infected fields;
- Regular disinfection of farm tools;
- Implementing disinfection points in frequent access points;
- Killing and removing diseased and neighboring plants/mats;
- Building channels around the infected plants to limit the movement of superficial water with bacterial inoculum;
- Elimination of secondary host plants (weeds that can host RSSC strains);
- Removal of male flowers (de-budding);
- Early bagging of fruit clusters.

Many Banana plants are grown in small plantings in backyards, on unattended land or even as volunteer plantings. The role of these productions in people's livelihood strategies might hence not always be very significant. There will hence always be a good number of diseased plants left in the farming landscape that continuously provide sources of inoculum (Blomme et al., 2014).

2.6.2.2. Inflorescence

The male inflorescence part is the primary infection site for insect vectors and no infection occurs when male buds are removed just after the formation of the last fruit hand, i.e., before the first cushion of male flowers is exposed (Blomme et al., 2017).

2.6.2.3. Cleaning tools

Cleaning of tools during routine plantation and sanitation practices can be done using a 20% solution of household bleach (sodium hypochlorite, NaOCl, 3.5%). Some ammonia-based disinfectants have proven to be effective in eradicating bacteria on farm tools, with the advantage that they are not corrosive, bio-degradable and more stable than sodium hypochlorite (Pérez-Vicente and Martínez de la Parte, 2015).

2.6.2.4. Buffer distance

Buffer distances of over a mile without Bluggoe bananas can significantly reduce spread of Moko disease, although infrequently distances exceeding five miles have been bridged (Buddenhagen and Elsasser, 1962).

In Belize, Moko disease was effectively eradicated following systematic surveys of ABB type Bluggoe mats and smallholder dessert banana cultivars, coupled with glyphosate treatment of all infected mats and all adjacent mats within a 5 m radius around infected mats (Thwaites et al., 2000).

2.6.2.5. Roguing and disposal of contaminated plants

Roguing is an essential element of any disease control strategy. However, in the case of bananas and plantains, the laborious nature of uprooting a mat and then disposing of the infected materials severely compromises the effectiveness of this technique (Blomme et al., 2014; Blomme et al., 2017). The removal/destruction of the infected Musa debris/materials has been cited numerous times as a hindrance to the implementation of region-wide Xanthomonas wilt control programs in East and Central Africa (Blomme et al., 2014). Digging a pit to bury infected plant debris is cumbersome and burning the debris is perhaps even more demanding, considering the large amounts of fuel wood required. In Indonesia, however, farmers managed to effectively control banana blood disease by burning uprooted material (Setyobudi and Hermanto, 1999).

Banana waste is not a favorable environment for growth of RSSC strains; and their survival will be limited to a very short period of time (Australia, 2008). RSSC strains are not competitive and are likely to be restricted to the vascular tissue of the waste in dry conditions. Under wet conditions that favor saprophytes, the competition from a diverse microbial community growing in banana waste is likely to include members that produce lytic enzymes and antibiotic substances harmful to RSSC strains. In compost the heat generated by microorganism metabolism will kill RSSC strains in hours

As regards the etiology of the Moko disease the continued removal of diseased plants in a field will reduce the inoculum level and lowers disease incidence below the economic threshold. It is hoped that single diseased stem removal (SDSR), together with the use of clean tools and de-budding will be effective (Blomme et al., 2014). SDSR have been proved as an efficient technique on the management of *Xanthomonas* wilt of Banana, but remains unclear and needs further investigation to control epidemics caused by other bacterial wilt pathogens. Variable degrees of systemicity for RSSC strains have been reported by (Denny, 2006), suggesting that it may be worthwhile to assess the SDSR technique under resource-poor farmer condition in areas affected by RSSC strains. The current control method for Moko in medium to large-scale plantations in Central and South America comprises the continuous and timely destruction (using herbicides) of all infected mats and those

located in a 5–8 m buffer radius around infected mats, coupled to strict restrictions in access to the treated sites until no new cases are reported (Blomme et al., 2017).

The burning of rice hulls is now common practice: they burn slowly and the high temperature totally inhibit the survival of bacteria and destroys the remaining corms (Blomme et al., 2017). Aerial plant parts should be chopped off all the way to the mat's base and followed by burning rice hulls immediately after chopping, and 3–4 weeks later (Blomme et al., 2017). The concerned area to must be subjected to quarantine measures.

2.6.2.6. Fallow and crop rotation

Fallowing is particularly challenging for small-scale Musa farmers and farmers should monitor for weeds that may promote survival of RSSC strains and remove them (Romo et al., 2012). Alternate hosts may act as reservoirs for infection complicating the implementation of control strategies, such as fallowing or crop rotation (Aritua et al., 2008).

The number of years that a rotation crop must be grown depends on the level of infestation, rigorousness of corm uprooting, survival capacity of the pathogen in local soils, climate (Blomme et al., 2017). At least a one-, but more often a 2- or 3-year rotation or fallowing is required to reduce RSSC population levels below the damage threshold (Denny, 2006). Sequeira (1962) reported for RSSC strains that fallows of 18 months lead to less than 1% disease incidence 12 months after replanting.

Farmers are often challenged in adopting fallow or crop rotation practices due to constraints of land availability and pressures to produce either a subsistence crop or one with high cash value (Blomme et al., 2017). This is particularly the case when the field has been affected by Moko, Bugtok or banana blood disease, due to the wider host range of RSSC strains (Belalcazar et al., 2004). The efficiency of a fallow period is compromised by the ability of the pathogen to survive in the absence of the primary host crop, either in the soil or on plant species that persist during the fallow period (Blomme et al., 2017).

Crop rotation has proven effective in reducing bacterial wilt populations. In Costa Rica, heavily infected banana plantations have successfully been rotated with velvet bean (*Mucuna pruriens*) for one or two cycles to reduce RSSC populations in the soil (Blomme et al., 2017).

2.6.2.7. Soil amendments

Soil amendments, such as organic matter (compost, rice husk powder and bagasse), inorganic fertilizers, or other material like oyster shell powder may modify soil microbial communities and result in suppressing the size or activity of the RSSC population (Blomme et al., 2017). These soil amendments have, however, not been widely studied and are not generally applied (Schonfeld et al., 2003; Lemaga et al., 2005; Saddler, 2005; van Elsas et al., 2005). Arenas et al. (2004) reported that incorporation of marigold (*Tagetes patula*) at 1kg/m² reduced RSSC populations in plantains by 85%.

In addition, a soil with a weak fertilization and an acidic pH favors the development of RSSC strains (Messiha et al., 2007).

2.6.2.8. Cultivar Tolerance/Resistance

Stover (1972) reported that all varieties of commercial bananas and plantains are susceptible to Moko disease. Bugtok disease is very common in backyards in the Philippines where 'Saba' and 'Cardaba' are planted. However, the following cultivars planted at the Davao National Crops Research and Development Center were also affected: 'Mundo,' 'Turangkog,' 'Paa Dalaga,' 'Biguihan,' 'Inabaniko,' and 'Java' (ABB/BBB genome); 'Gubao,' 'Katsila,' 'Pelipita,' 'Madu-ranga,'

(ABB genome) and ‘Giant Kalapua’ (ABBB genome). This indicates that cultivars possessing the ‘B’ or M. balbisiana genome are susceptible to Bugtok (Soguilon et al., 1995).

Similarly, in Central America, the clone ‘Pelipita’ (ABB genome) was distributed widely in the late 1960s as an Moko SFR strain resistant substitute for ‘Bluggoe’ after it was found to escape infection because of its persistent male bracts and flowers (Stover and Richardson, 1968; Gomez, 1977).

The development of bacterial wilt-resistant plants through conventional breeding also suffers from the problems of long generation times, various levels of ploidy, sterility of most edible cultivars and limited genetic variability (Tripathi et al., 2004). However, following artificial inoculation of 31 diploid (AA) genotypes (21 natural germplasm and 10 hybrids) with the Moko pathogen in a greenhouse in Brazil by (de Olivera e Silva et al., 2000), the hybrids F2P2, 1741-01, 1319-01, and SH3362 and ‘Babi Yadefana,’ a cultivar from New Guinea, showed resistance to the Moko pathogen. This demonstrates the occurrence of genetic variability among diploid (AA) banana genotypes in their ability to express resistance to RSSC strains causing Moko disease (Blomme et al., 2017).

3. FAI MOKO EXPERTISE

3.1. FIELD SAMPLING

Sampling was done in collaboration with FAI staff team. On site recognition of diseased plant to be sample on both Nickerie and Jarikaba estates were done prior this expertise mission. This has allowed saving time in order to be more efficient in the subsequent analysis steps. A total of 14 banana plants were sampled within the Nickerie estate; 2 sets of water samples in both Nickerie and Jarikaba estates; 2 soil samples in Jarikaba estate; 2 plantains, 2 sets of eggplants, 2 sets of pepper, 1 set of tomato were samples outside Nickerie estate, but within the Nickerie district; 8 sets of weeds in Nickerie estate; and 1 set of weed in Jarikaba estate.

Name	District	FAI info	Latitude	Longitude	Variety
Jarikaba Soil Sample	Jarikaba	Jarikaba	5.8030837	-55.3431813	na
Jarikaba Soil Sample	Jarikaba	Jarikaba	5.807246	-55.352898	na
Jarikaba Water Sample	Jarikaba	Jarikaba	5.8153076	-55.357359	na
Nickerie Water Sample	Nickerie	Nickerie	?	?	na
NEgg#1	Nickerie	outside FAI	5.8862449	-56.950907	na
NEgg#2	Nickerie	outside FAI	5.8397624	-56.9988411	na
NPepper#1	Nickerie	outside FAI	5.885997	-56.9508778	na
NPepper#2	Nickerie	outside FAI	5.8388067	-56.9981871	na
NTomato#1	Nickerie	outside FAI	5.8395469	-56.9977526	na
NBS#1	Nickerie	720	5.8739456	-56.9602361	Williams
NBS#2	Nickerie	853	5.8728857	-56.9620572	Williams
NBS#3	Nickerie	899	5.8731776	-56.9644571	Williams
NBS#4	Nickerie	953	5.8720737	-56.9621686	Williams
NBS#5	Nickerie	911	5.8719321	-56.9598398	Williams
NBS#6	Nickerie	1021	5.8716618	-56.9602573	Williams
NBS#7	Nickerie	1121	5.8698435	-56.9605758	Williams
NPlantain#1	Nickerie	outside FAI	5.8872028	-56.9508267	Plantain
NPlantain#2	Nickerie	outside FAI	5.8966667	-56.9504603	Plantain
NBS#10	Nickerie	K23 B5	5.86618	-56.958364	Williams
NBS#11	Nickerie	K23 B118	5.8633141	-56.955064	Williams
NBS#12	Nickerie	K23 B96	5.8613981	-56.955616	Williams
NBS#13	Nickerie	K19 B67	5.866532	-56.955007	Williams
NBS#14	Nickerie	K19 B73	5.866757	-56.95482	Williams
NBS#15	Nickerie	K20 B63	5.86546	-56.955794	Williams
NBS#16	Nickerie	K21 B46	5.864647	-56.956903	Williams
Unknown vine	Nickerie	na	na	na	na
Cissus Sicyoides	Nickerie	na	na	na	na
Momordica charantia	Nickerie	na	na	na	na
Unknown weed	Nickerie	na	na	na	na
Ruellia Tuberosa	Nickerie	na	na	na	na
Eleusine indica	Nickerie	na	na	na	na
Montrichardia arborescens	Nickerie	na	na	na	na
Heliconia psittacorum	Nickerie	na	na	na	na
Heliconia psittacorum	Jarikaba	na	na	na	na

Table 2 - Field samples

3.2. LABORATORY ANALYSIS

All laboratory work was done at the CELOS facilities, in the University of Suriname, under the kind supervision of Dr. Imana POWER.

3.2.1. Banana FAI Estates

A total of 14 Moko suspected banana plants were sampled on the Nickerie banana estate only, as no diseased suspected banana plants were spotted in the Jarikaba estate during the expertise. Nevertheless, FAI team searched for diseaded plants meanwhile and spotted few cased following the next months. Isolation and characterization was performed by CELOS laboratory.

Results: All Banana samples from Nickerie were positive for the presence of strain of the RSSC: Phylotype IIA-6 isolates were characterized. Samples scouted after the expertise in Jarikaba were positive for the presence of of strain of the RSSC: Phylotype IIB-4 isolates were characterized.

3.2.2. Other collected samples

3.2.2.1. Plantain

A total of two plantain samples were collected on the outside of the Nickerie estate, were other *Solanaceae* were growing (NPlantain#1), or close to a water course (NPlantain#2).

Results: All Plantain samples were positive for the presence of strain of the RSSC: IIA-6 isolates were characterized.

3.2.2.2. Wild compartment -weeds

Weeds were collected on the Nickerie estate close to Banana Moko cases, in order to assess the presence of Moko within the wild compartment (meaning “not cultivated”); and in Jarikaba (*Heliconia psittacorum* only). Hypothesis suggesting Moko inoculation is hence assessed by this mean. Note here that few weeds were collected: as a first approach, sampling did not constitute a proper statistically sounded protocol.

1. Unknown vine
2. *Cissus Sicyoides*
3. *Momordica charantia*
4. Unknown weed
5. *Ruellia Tuberosa*
6. *Eleusine indica*
7. *Montrichardia arborescens* (Moko Moko)
8. *Heliconia psittacorum*

Some collected weeds were previously identified in the literature to harbor cells in high density of RSSC strains, without showing any symptoms, such as *Montrichardia arborescens* and *Heliconia psittacorum*. Samples of the same nature, sampled in different places of the Nickerie estate, were pooled for analysis purpose.

Results: All wild compartment samples were negative for the presence of any strains of the RSSC but no conclusion could be drawn from this analysis.

3.2.2.3. Wild compartment - Soil and Water

In order to assess the presence of Moko or strains part of the RSSC, soil and water samples were scouted. A total of four water samples (two in Jarikaba, and two in Nickerie) and two soil samples (Jarikaba only) were send for analysis. Water samples were retrieved on main irrigation system on both estates (Jarikaba and Nickerie); while soil samples in Jarikaba were retrieved on former Moko cases area.

Note here that issues were encountered during the analysis process for both of the samples: water and soil were containing too much thin particles that prevented a proper filtration; hence, analysis results are not to be taken as reliable, if negative.

Results: All soil and water samples were negative for the presence of any strains of the RSSC but no conclusion could be drawn from this analysis.

3.2.2.4. *Solanaceae*

Close to the Nickerie estate, samples from *Solanaceae* cultivated plants were scouted in order to determine if RSSC strains could be found elsewhere FAI estates. These occurrences may represent an additional threat to the banana cultivation and more generally, to the Suriname territory. A total of two cultivated zones were scouted and yielded one sample of eggplant (NEgg#1) and pepper (NPepper#1); and on another cultivated zone, samples were pooled according to their species, and yielded one eggplant sample (NEgg#2), one pepper sample (NPepper#2), and one tomato sample (NTomato#1). Note here that as a first approach, sampling did not constitute a proper statistically sounded protocol.

Results: All *Solanaceae* samples were negative for the presence of any strains of the RSSC but no conclusion could be drawn from this analysis.

3.2.3. Results and conclusion

From the sampling and the analysis performed in both Jarikaba and Nickerie, here are the main conclusion that can be drawn:

- All Moko-diseased-suspected banana plants in the Nickerie estate were characterized as positive for the presence of Moko strains belonging to the RSSC. Same conclusion for the Plantain plants sampled outside Nickerie. Isolates were characterized as Phylotype IIA-6.

- Moko-diseased-suspected banana plants in the Jarikaba estate were characterized as positive for the presence of Moko strains belonging to the RSSC. Isolates were characterized as Phylotype IIB-4.

- All other samples: soil, water, weeds, cultivated *Solanaceae*, are negative for the presence of any strains belonging to the RSSC.

Isolation of strains has been done by plating plant extract on both Kelman and Sequeira solid medium for 48 to 72h at 28°C.

Characterization of strains has been done by performing the N-Musa multiplex (NMmx) conventional PCR (Prior and Fegan, 2005; Das et al., 2006).

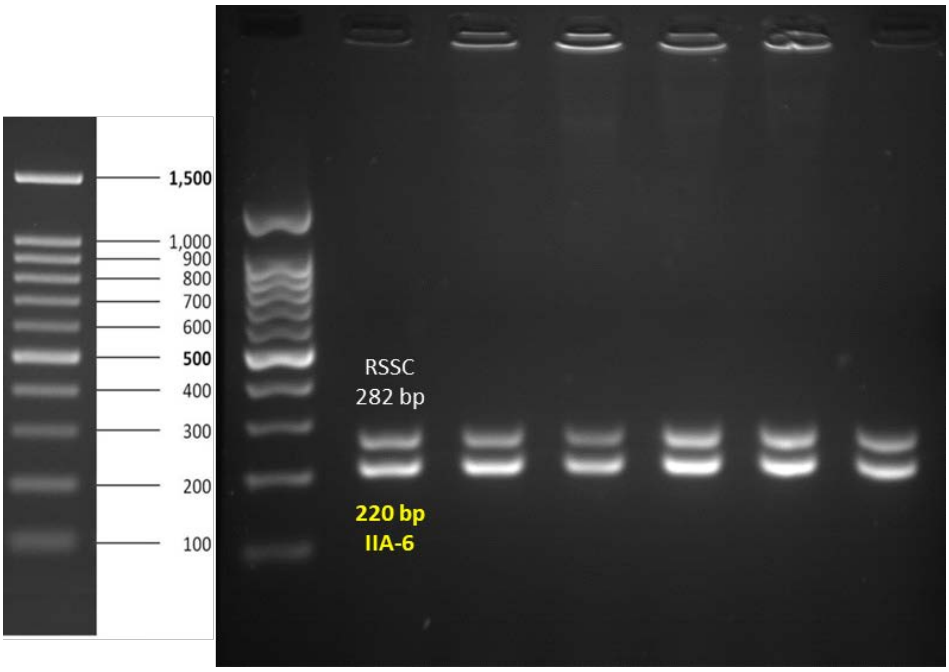


Figure 3 - Gel electrophoresis of PCR amplified products from the Nickerie estate through the Moko N-Mmx conventional PCR; only few lanes are shown as every lanes gave the same results.

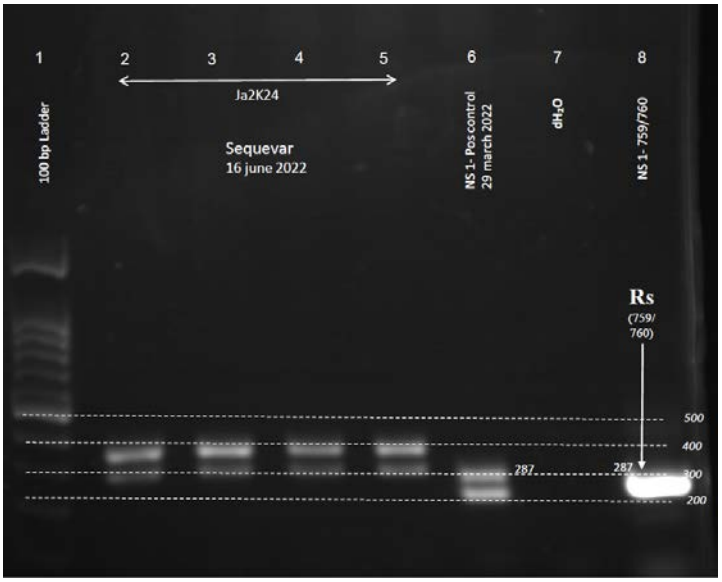


Figure 4 - Gel electrophoresis of PCR amplified products from the Jarikaba estate through the Moko N-Mmx conventional PCR ; only few lanes are shown as every lanes gave the same results.

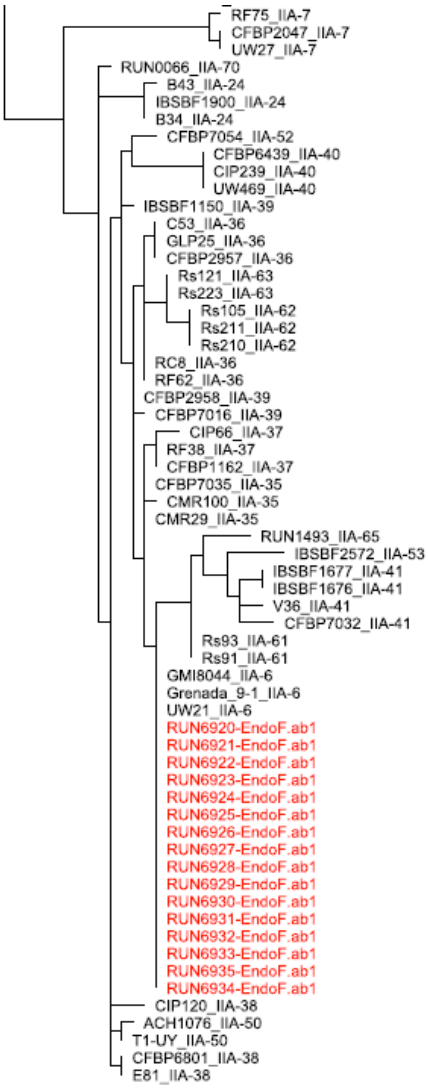


Figure 5 – Phylogenetic tree (close up) based on sequencing of partial sequencing of the endoglucanase gene (*egl*). Strains in red are from this expertise; Phylotype IIA sequevar 6 (IIA-6) has been characterized.

Jarikaba: Evolution of the Moko situation between 2009 and 2021 (Google Earth)

Google Earth Nov 2009

Google Earth Oct 2011

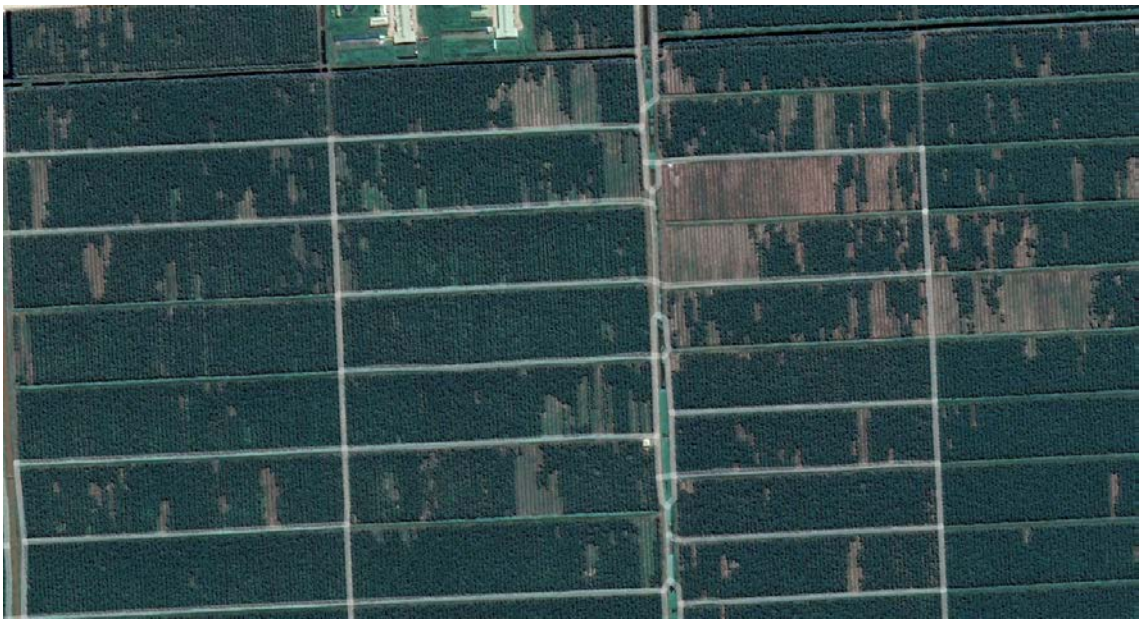
Google Earth Sept 2015

Google Earth Aug 2018

Google Earth Aug 2021

Nickerie : Evolution of the Moko situation between 2017 and 2020 (Google Earth)


Nickerie 2017



Nickerie 2019

Nickerie 2020

Evolution of the disease appears to be in an “island” configuration, radiating from a spot and speading around it, from different spots within the estate. This type of diffusion can be associated to both insects: many different and distant spots, with high speed diffusion; and water/weeds: enlargement of the affected area from an old diseased spot.

Positive samples found in the Nickerie district were all associated with either Banana plants or Plantain. At this point of analysis, no other RSSC strains were retrieved from the wild compartment (weeds/water/soil) or cultivated *Solanaceae*. Nevertheless, the statistical sampling was not done properly on the wild compartment and *Solanaceae*; therefore, caution should be made on result interpretations.

Same observation of the disease systemicity was done in the previous FAI report (Prior et al., 2015): infected plants showed that most of the bacterial infections are “ascending”; from the bottom of the plant (strain) to the top of the plant (leaf sheaths forming the pseudo-trunk, leaf stalk and flower stem).

Strains retrieved in the Nickerie estate from diseased Banana/plantain were all typed as Phylotype IIA Sequevar 6 (IIA-6). Following the old classification system, these strains are associated with the SFR Moko type, which were characterized as strains forming small, fluidal, and round colonies; mainly transmitted by insect; and highly pathogenic.

Because there was a single lineage scattered across the Nickerie estate, hypothesis of a single introduction successfully distributed within the plantation (insects and contaminated tools) is mostly prevalent. Hypothesis of contamination by *in vitro* plant is not supported here, as the progression is mostly island-shaped and health of *in vitro* plant checked.

Two plantains were characterized as Moko infected plants by the same Phylotype IIA-6 strains as other banana plants within the Nickerie estate. This means that the disease is in the environmental landscape of this estate. As established, the disease pressure will put at risk the banana production, especially through insect transmission means. A proper management of flower bud must hence be strictly observed.

Moreover, strains retrieved in the Jaraikaba estates were characterized as Phylotype IIB Sequevar 4 strains (IIB-4). A great risk is their introduction in the Nickerie estate, and vice versa. Former characterization of Moko strains in Jarikaba (Prior et al., 2015) also identified Phylotype IIB Sequevar 4 strains (IIB-4) as causing the Moko disease. They conclude that Phylotype IIB-4, just as the IIA-6 lineage identified in Nickerie in 2022, is widely distributed in Central America, Venezuela, Columbia, and the Caribbean. Origin of introduction remains unknown. What can be drawn from factual data is that neighboring countries also have reported cases of Moko and were typed:

- Guyana: IIA-6 and IIB-4
- French Guyana: IIB-4
- Brazil: IIB-3, IIA-24, IIA-41, IIA-53, and IIB-25
- Colombia: IIB-4 and IIA-6
- Venezuela: IIA-6
- Grenada: IIA-6
- Saint Vincent and The Grenadines: IIB-4

Prophylaxis is well observed on both estates: operators disinfect their shoes/tools and quarantine of diseased plant followed by eradication with rice hulls is done in a 10 m area.

Soil in both estates are typed as 'vertisols', which are suppressive for bacterial disease, including RSSC Moko causing strains. Good fallow practice must be strictly observed in order to lower the inoculum pressure and hence start plantation with a healthy environment. At least a one-, but more often a 2- or 3-year rotation or fallowing is required to reduce RSSC population levels below the damage threshold; and fallows of 18 months lead to less than 1% disease incidence 12 months after replanting. The efficiency of a fallow period is compromised by the ability of the pathogen to survive in the absence of the primary host crop, either in the soil or on plant species that persist during the fallow period.

- Taking out weeds and other plants that can host RSSC strains: avoid RSSC natural reservoirs that will spoil the fallow efficiency;
- Flooding the soil (wet fallow) in order to create a positive killing effect on Moko strains (and other bacteria) by setting up competition among microorganisms and unfavorable environment;
- Desiccating the soil (dry fallow) beyond pF[2] 4 will mechanically crush the bacteria under high pressure, resulting in a significate decrease of bacterium inoculum pressure.

As stated in the previous FAI report (Prior et al., 2015), we did not observe many insect-transmitted cases on the plantation, and it is anticipated that all recommendations to prevent distribution by contaminated tools should result in effective control of Moko in the short term. The new recommendation is to observe a strict fallow (wet/dry) period and weed management in Nickerie in order to establish a viable environment for banana production.

Important highlights:

We particularly recommend that weeds must be destroyed during the flooding period in order to avoid bacteria survival in weeds (many plants can host *R. solanacearum* strains). This part of the fallow itinerary practice must be improved since many fallows obserd (particularly in Nickerie) showed important weed covers and a bad elimination of banana trees (picture below).

We also recommend to assess the quality of the fallow at the different steps in order to better understand Moko disease epidemics after replantation. It might already be possible to link epidemics of new planted area with such practices and we recommend to make such evaluation.

Recommandations:

- Destruction of banana trees (may be with blank desuckering at the beginning to avoid regrowth
- Using a shovel (grader) to level

[2] pF is the decimal logarithm of the suction expressed in centimeters (head) of water.

- Destruction of weeds
- Increase walls
- Filling with water at 40 com above ground and full coverage for 6 months
- 6 months of dry land including weeding and restoration of the drains as soon as the water is dry

As two different strains were retrieved from the Jarikaba and Nickerie estates, it is of **upmost importance to contain each strain in their respective geographic area** by setting up drastic prophyloactic actions.

Bad fallow practice : bad destruction of banana plants. Many weeds survive and can maintain bacterial inoculum

Further diagnostic could be done on water samples from main irrigation channels and shipping them to another laboratory specialized in RSSC water analysis. For the weed management, a grass cover protocol could be set up, in order to outcompete the growth of undesirable weeds that can host RSSC strains. Please refer to Appendices for known RSSC and verified Moko host plants (note that a RSSC host plant can also host Moko strains, but are unverified).

As a reminder, two different strains are present on the Surinam territory: Phylotype IIA-6 (Nickerie 2022) and Phylotype IIB-4 (Jarikaba 2015 & 2022). The fight against RSSC strains is all the more difficult than it should be a matter of a nationwide preoccupation. Effort to reduce the population of RSSC within both estates should be accompanied with prophylactic measures around the estates and at a more global scale to lower the wild compartment disease pressure and makes the banana cultivation economically viable. More information need to be collected on this specific wild compartment (weed, soil and water) in order to better size the collective effort to set up in Surinam.

4. SIGATOKA DISEASES

4.1. PRESENCE OF BLACK SIGATOKA IN FAI FARMS

Black Sigatoka has still not been officially reported in Surinam. During this mission we have paid a particular attention to specific detection of *Pseudocercospora fijiensis* in the farms of Jarikaba and Nickerie.

4.1.1. Black Sigatoka has totally replaced Yellow Sigatoka in Jarikaba farm

During the visit of Jarikaba farm we visited two plots : Jarika 2 – plot 17 and Jarikaba 3 plot - 21.

In both plots we could observe typical symptoms of Black Sigatoka on all plants. These symptoms are brown streaks visible at the lower leaf surface and generally observed at high density (photos below for different stages). Necrotic stages are poorly present because of good and efficient deleafing practices.

Leaf samples were analysed in the laboratory of CELOS, in the University of Suriname, under the kind supervision of Dr. Imana POWER. The lower surface of single stage 2 lesions were applicated on water agar medium to collect conidia. Typical *Pseudocercospora fijiensis* conidia could be observed which do not occur with *Pseudocercospora musicola* that sporulates only on the upper surface of stage 4 lesions. **There is absolutely no doubt that this is Black Sigatoka**.

Young streaks of BS : mainly stage 2

Older lesions of BS : mainly stage 3

Stages 4 to 6 of BS

<u>Important highlight :</u>

Even if chemical control is uniform in Jarakibaka, we could notice that Black Sigatoka impact was not the same in Jarikaba 2 (poor drainage) and Jarikaba 3 (good drainage). The number of leaves at harvest was very low in Jarikaba 2 (between 1 and 3) and much higher in Jarikaba 3 (between 5 to 7). **This difference is only due to the foliar emission rate and agronomic practices.**

Low number of leaves at harvets (<1 to 3) in Jarikaba 2 with poor drainage

Higher number of leaves at harvest in Jarikaba 3 with good drainage (between 5 and 7)

4.1.2. Black Sigatoka has (probably) recently arrived in Nickerie farm

In Nickerie Yellow Sigatoka is still dominant. Typical symptoms are present : yellow streaks at the upper surface of the leaf (photo below)

Typical symptoms of yellow Sigatoka (yellow streaks)

However, typical symptoms of Black Siagatoka could be also be observed on older leaves that had been deleafed (photo below).

Stage 4 lesions of BS present on cutted leaves

Those lesions were also analysed in Celos laboratory and also showed the presence of typical *P. fijiensis* conidia, **showing undoubtedly that Black Sigatoka is present in Nickerie** even if it has still not replaced YS, what should happen in the next future.

The coefficient table used for disease monitoring is not the same for YS and BS. Particularly, the table for BS includes an increase of coefficient values when a high density of symptoms is noticed on the leaf inspected. This is a particular trait of BS because the evolution from yong streaks to necrotic stages is very fast when density of infection is high. The changes are presented below :

Coefficients attributed to the different [banana tree leaf number / stage of the Sigatoka disease] associations.

Stage of the disease	Leaf number				
	I	II	III	IV	V
1	100	80	60	40	20
2	120	100	80	60	40
3	–	120	100	80	60
4	–	–	120	100	80
5	–	–	–	120	100

Old table for yellow Sigatoka (Sigatoka disease)

Coefficients attributed to the different [(leaf number)–(stage of the disease)] associations for banana trees affected by the Black Leaf Streak disease of bananas and plantains [3].

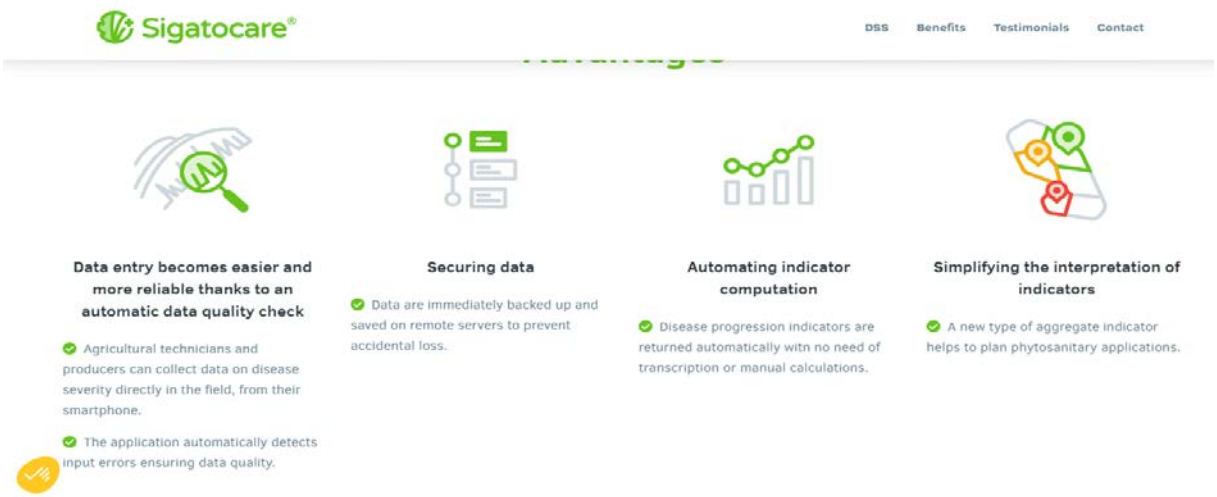
Stage of the disease[1]	Density of lesions	Leaf number		
		No. 2	No. 3	No. 4
1	–	60	40	20
	+	100	80	60
2	–	100	80	60
	+	140	120	100
3	–	140	120	100
	+	180	160	140
4	–	180	160	140
	+	220	200	180
5	–	220	200	180
	+	260	240	220
6	–	260	240	220
	+	300	280	260

[1] For each stage of the disease, the mark attributed depends on density of lesions, which is estimated by "–" if there are less than 50 outward signs and by "+" if there are more than 50 outward signs.

New table for Black Sigatoka (Black Leaf Streak disease)

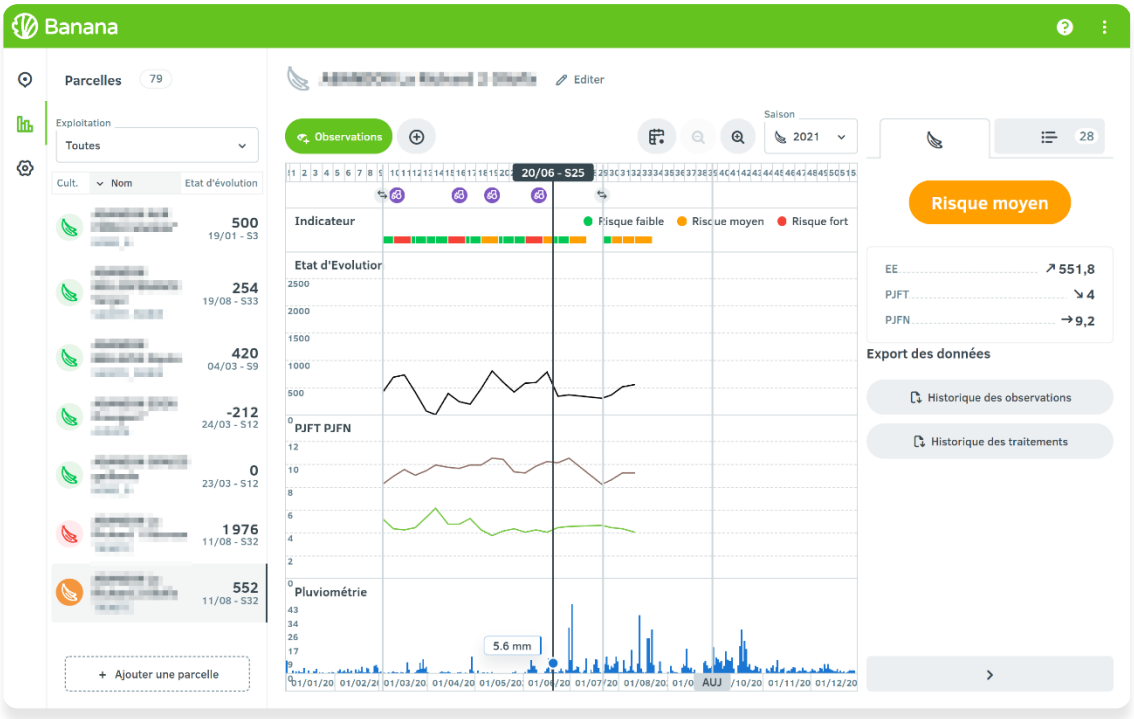
By another hand more disease parameters should be monitored and used for decision making. Particularly, specific attention should be paid to density of lesions, to the youngest leaf with streaks (YLSt, a good estimate of incubation and latent period), to the youngest leaf with spots (YLS, a good estimate of the total duration of the life cycle of the pathogen) whose evolution is usefull to understand if disease is controlled (de Lapeyre de Bellaire, L., et al. (2010). "Black Leaf Streak Disease is challenging the banana industry." Fruits **65**(6): 327-342;).

Particularly for Black Sigatoka, decision is a complex analysis of all these disease parameters. In collaboration with ITK (a private company involved in the development of software for agriculture) we have developed a new numeric tool (Sigatocare ®) that is aimed to support decisions. The tool is summarily described below and might be used by FAI staff.



Functionnalities included in the Software

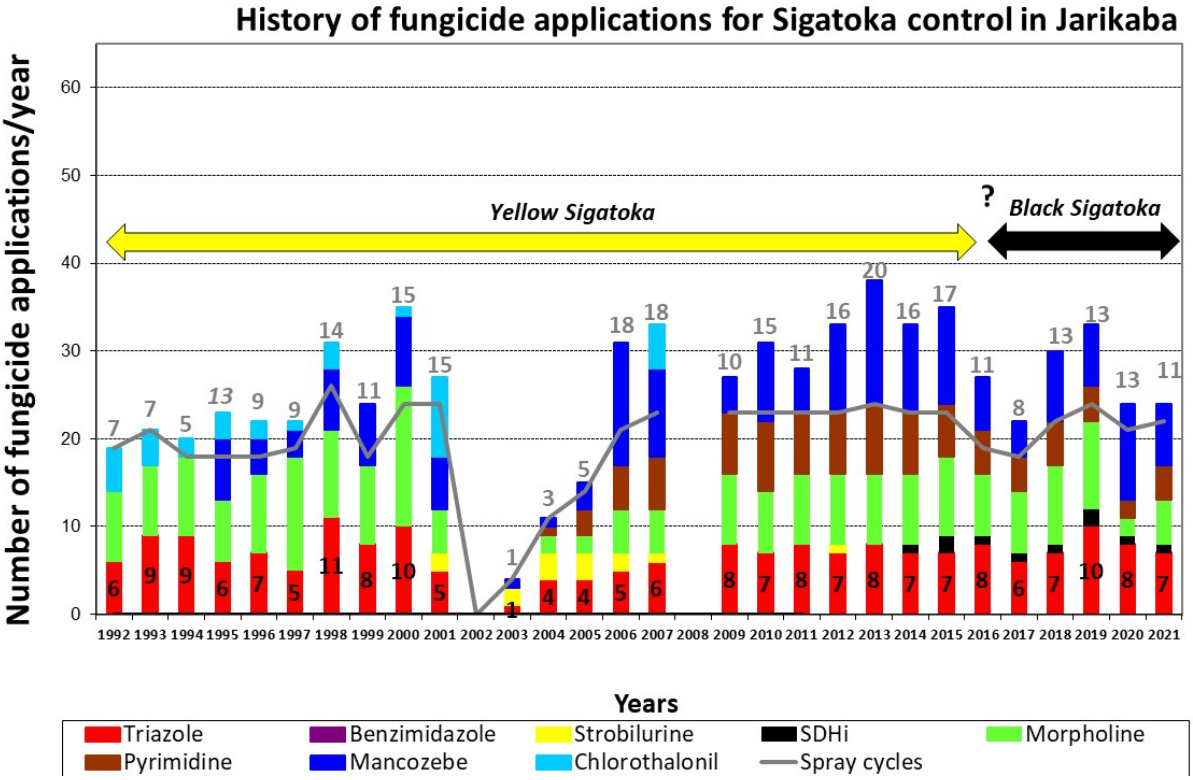
Data introduction on Smartphone



Example of automatic graphical representation and decisions (green, orange, red)

4.3.1. Diagnostic of practices

In former visits, we had the opportunity to establish this diagnostic from 1992 to 2007 for Jarikaba and we have completed with the most recent data. We represent here this evolution over this 30 years period where we assume that BS arrived probably around the years 2015-2016 (T. lescot observed symptoms on plantain around Jarikaba farm in 2015, but did not observe BS in the farm).



History of fungicide use for Sigatoka control in Jarikaba farm from 1992-2021. Here the number of applications represent the total use of fungicides. Grey lines represent the total number of cycles which is less important thant the number of fungicide application when several fungicides are mixed in a same cycle. BS presence is estimated by 2016 but cannot be verified. Black numbers on red bars represent the number of DMI (triazole) fungicide applied during the year ; Grey numbers upon the bars represent the amount of active ingredient used during the year

Here we must consider that the number of fungicide applications is often higher than the number of sprays because in many occasions 2 to 3 fungicides were mixed in a same spray cycle.

Many comments can be done about this history on fungicide use in Jarikaba :

4.3.1.1. Too many uses of triazoles

DMI fungicide use (triazoles) has been vey important during the period with YS (red bars in the graph). Up to 11 applications have been done with this type of fungicide (propiconazole, epoxyconazole, difénoconazole, tebuconazole) which are the most effective fo Sigatoka (yellow or Black) control. **This is too much and might lead to fungicide resistance**. It is **highly probable that fungal populations of *P. musicola* (YS) have a reduced sensitivity to DMI fungicides** which is probably not a problem in Jarikaba beacause of the prevalence of BS, but might be still the case in Nickerie. The **sensitivity of incoming *P. fijiensis* populations might be good** to many fungicides as observed in the Caribean after the expansion of BS, **but must be checked rapidly since BS might be present in jarikaba for more than 5 years now and P. fijiensis has been exposed to DMI fungicides**. Anyway, **it is very important to preserve the efficiency of DMI fungicides** and to limit their use : 7-10 applications have been done in the last 4 years, which is too much. We recommand to **limit the use of triazoles to 4-5** per year.

4.3.1.2. Fungicide use seems to be less important during the last 5 years

Even if the total number of sprays has not varied so much (grey line in the graph), the total number of fungicide applications has changed a lot durin the period considered. Fungicide use has been more important from 2012 to 2015 because of a more important use of contact fungicides (mancozebe) almost reaching a total of 40 fungicide applications/year in 2013. In a same way, the amount of active ingredient applied/ha/year has been more important at that time (16-20 kg/ha/year).

Fungicide use is less important since 2016 and appears as a paradox because BS control is known as being more difficult than YS control and generally requires more fungicide use. **This might be linked to a better efficiency of chemicals on *P. fijiensis* fungal populations than on *P. musicola* that have been exposed during a very long period to most fungicides**.

4.3.1.3. Some mixtures of fungicides are useless

For some fungicides the risk of resistance is very negligible and the association with a contact fungicide (mancozeb) has no real benefit.

This is the case of pyrimethanil (Siganex) or morpholines (impulse, volley, fenpropimorh) that do not need to be associated with mancozeb (Dithane, mancozeb, vondozeb).

4.3.2. Some recommandations

Here are some general recommandations:

- As mentioned earlier limit triazole use in order to extend their efficiency over time
- Increase the use of morpholines that do not need to be used with mancozebe
- Incorporate new chemical fungicide families in order to diversify the mode of actions and to limit fungicide resistance : benzimidazoles (i.e thiophanate-methyl : 1 to 2 applications/year); strobilurines (azoxystrobine, trifloxystrobine, pyraclostrobine : 1 to 2 applications/year); SDHI (Boscalid, fluopyram : 1 to 2 applications/tear)
- Use straight oil (15l/ha) in some occasions when disease pressure is low
- Maintain good deleafing practices which are important in order to limit disease expansion, but also to mitigate disease effect on banana greenlife
- Provide good agronomic management that is essential for a better performance of the chemical strategy. For instance, good drainage looks to be essential.

5. PESTS MANAGEMENT

- **Black weevil** (*Cosmopolites sordidus*) : very few impact, but implementation on survey : pheromone traps could be used to monitor the presence and prevalence of the weevil

- **Nematodes** (*Radopholus, Pratylenchus*) : no visual impact (?) ; analysis on roots (lab facilities & protocol ?) ; 1 analysis each year ?
-
- Others :
    - Flower thrips (*Frankliniella parvula*?) : Early bunch cover application ; dry flower removal in the field ; 'Spinosad' ; encourage natural enemies

    - Red mites (*Tetranychus* ?), } Importance (impact?)
    - Mealybug (*Pseudococcus* ?), } Seaisonality ?
    - Caterpillar (*Antichloris viridis* ?) } Biodiversity (cover plants ?)
      Biologicall equilibrium

6. AGRONOMIC MANAGEMENT

6.1. DRAINAGE AND WATER MANAGEMENT

Importance of drainage on yield: choking, bunches weight …

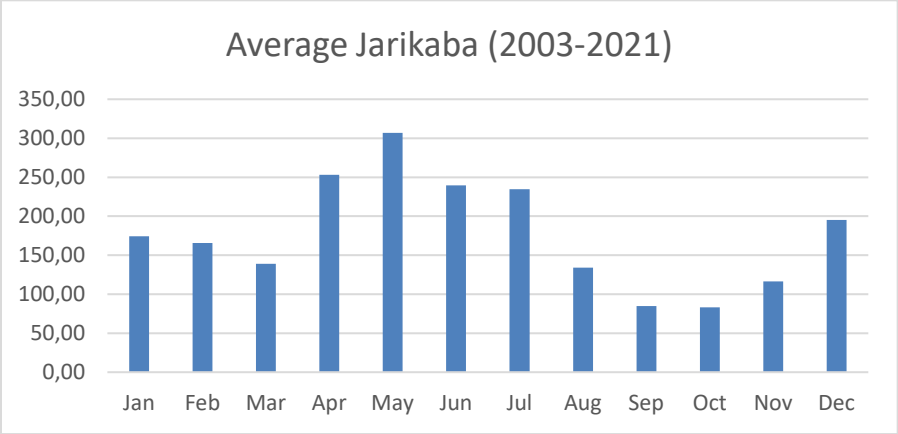
We could notice that drainage was vey bad in many parts of Jarikaba affecting bunch weight but also the impact of BS.

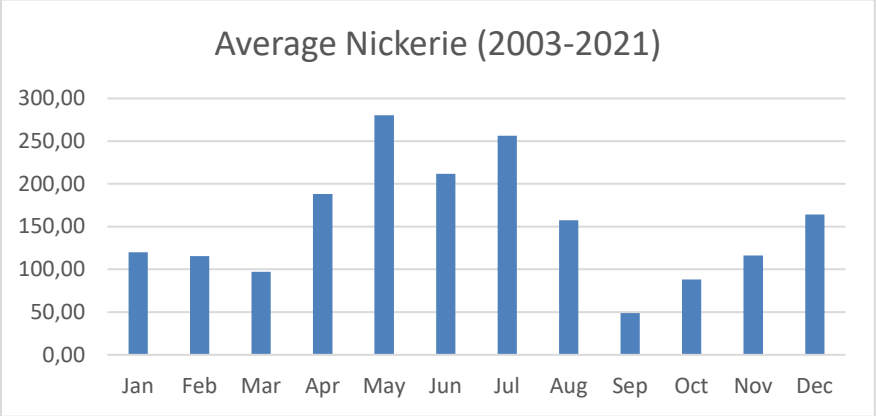
Important improvements were noticed where drainage was correctly done.

6.2. IRRIGATION

Objectification of the needs in relation with the expert report (Jacques Bourgade)

- Production versus rainfall
- Rainfall : historical statistics of durations without any rain (September ?)
- Evaporation (ETP – ETM) ?
- Tensiometer ?





6.3. CULTURAL PRACTICES

- **Humanpower**: we could notice that **this was a very important limiting factor in Jarikaba**: significant delays in drainage management, weeding, desuckering, bagging,

harvest … For instance in some cases bunches could not be harvested because of a lack of manpower.

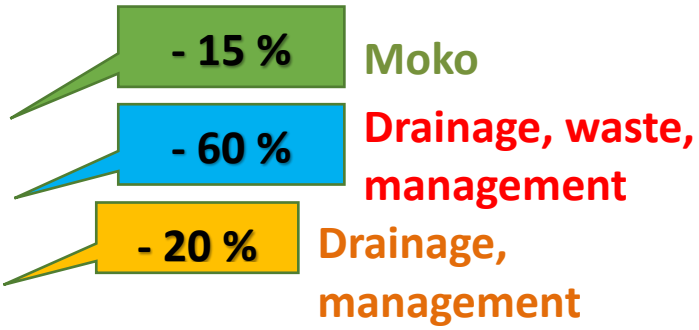
- **Weeds control** : cover plants (trials with some specifics species)

6.4. PRODUCTIVITY AND YIELD CONSTRAINTS

Yields in 2012 are very low as compared with 2014. Several yield components are affected like density of plants (Moko effect); the ratio bunch/box (agronomic management, banana selection in packing stations and % of waste), the ratooning (consequence of agronomic management).

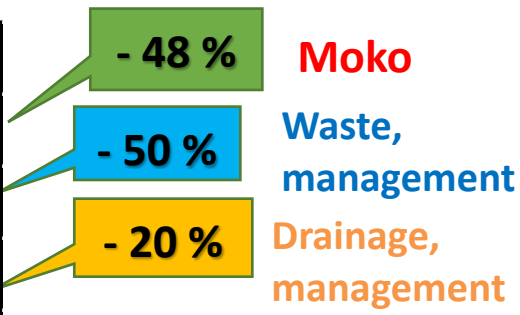
Jarikaba :

	2014	2022
density	1900	1600
box/bunch	0,87	0,35
ratooning	1,6	1,3
Yield	49	13



Nickerie :

	2017	2022
density	1900	1000
box/bunch	0,75	0,38
ratooning	1,6	1,3
Yield	42	9



- The main limiting factor are drainage in Jarikaba, Moko in Nickerie
- No nutrient deficiencies observed, but need soil-leaf analysis

- (evolution of soil organic mater rate – prevention with external vegetal and animal organic mater supply (compost) ?)
- Permanent maintenance of density is required, especially in Nickerie

6.5. POST HARVEST

- Harvest is still done on the thermic sum basis : 
- Important waste in the packing house : 45 % : ☹

6.6. VARIETIES

- Base : 'JOBO' & 'CV 902'
- Reduction of 'William' (Nickerie)
- 1 plot (Jarikaba & Nickerie) with 'RUBY' (MA13)

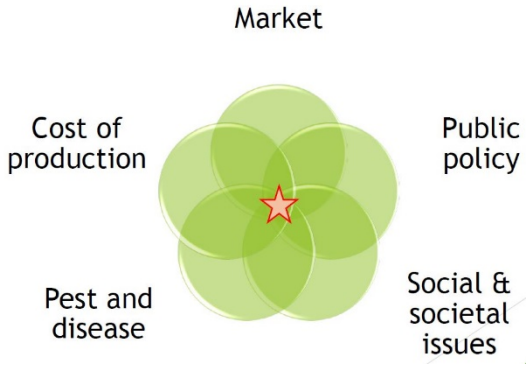
European Banana Market

Access to the European market: sustainability at the heart of the debate

The European banana market is the world's largest import market. It is also the most demanding in the world in terms of complexity of the demand and one of the most competitive in economic terms. Unlike the American markets (United States and Canada), it is also a very dynamic market in terms of consumption, particularly in the Member States that have joined the last, i.e. the countries of Eastern Europe.

In a remote presentation, we presented the main forces acting on the European market that are all parameters to be taken into account for a return of Surinamese origin to the market. Knowing that each constraint can correspond to an opportunity.

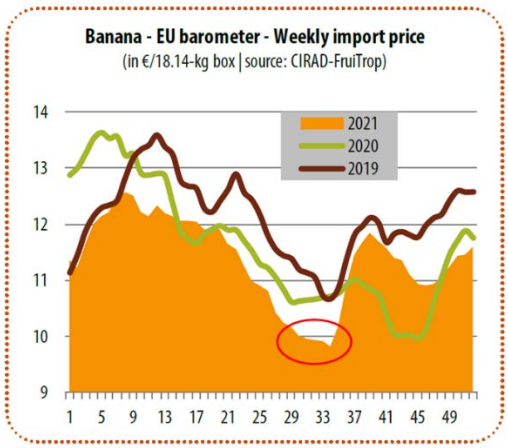
The main forces of change can be grouped into 5 main themes: the market, production costs / competitiveness, diseases and pests, public policies and finally social and societal themes.



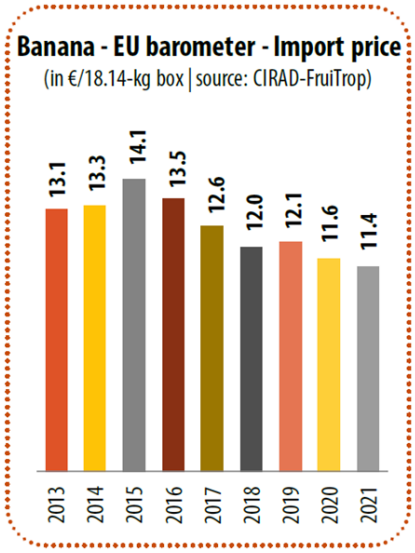
MARKET TRENDS IN EUROPE

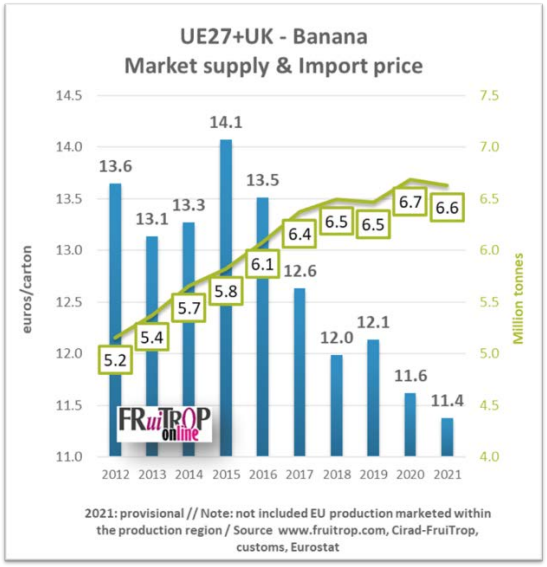
It should first be noted that ACP origins, i.e. Suriname, benefit from a tariff advantage of 75 euros / tonne compared to other suppliers on the European market (excluding European production). ACP countries do not pay customs duties while Ecuador, Costa Rica, Colombia, etc. pay a duty of 75 euros / ton (1.36 euros / carton) on entry into the EU.

On the market evolution side, the observation is simple and depressing. Here is the evolution of the barometer of import prices in Europe, a barometer that our magazine FruiTrop (www.fruitrop.com) publishes every week. In 2021, it has never been so low on an annual average, reaching 11.4 euros/carton. It has also never been so low on a weekly basis. The €10 fund was crossed in week 33 of 2021!

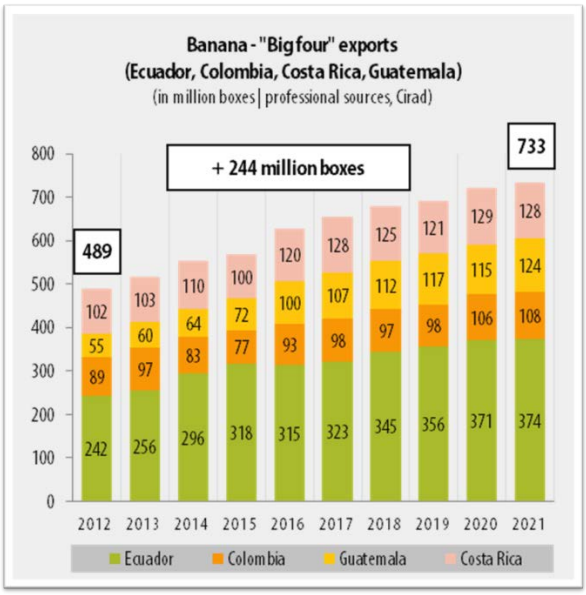


The trend is heavy. Indeed, the collapse of the European price was 2.7 euros/carton between 2015 and 2021. The European market is one of the most competitive in the world. In terms of volume, however, it is a success and one of the only markets in the world that has experienced such a long and intense period of growth. This growth has benefited Latin American organizations. The proof. Since 2010, Latin American origins have exported an additional 1.5 million tonnes to the European market. At the same time, the contribution of Caribbean and African (ACP) exports and European production remained stable.





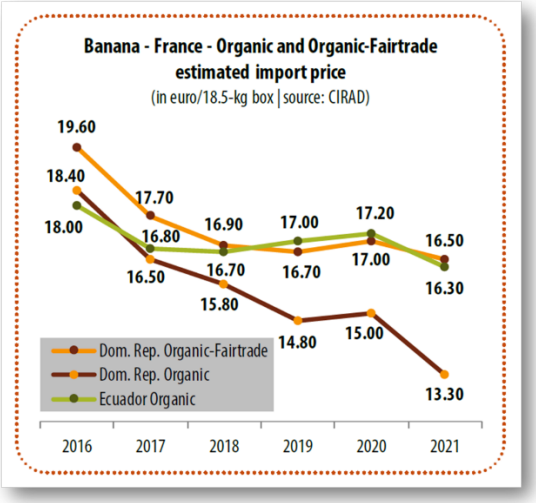
The downward pressure on prices, particularly in Europe, is naturally explained by a very significant increase in the supply of Dollar bananas. Global supply has increased considerably over the last decade as evidenced by the evolution of exports from the "BIG FOUR (Ecuador, Costa Rica, Colombia and Guatemala)" which accumulated a surplus of 244 million cartons between 2012 and 2021.



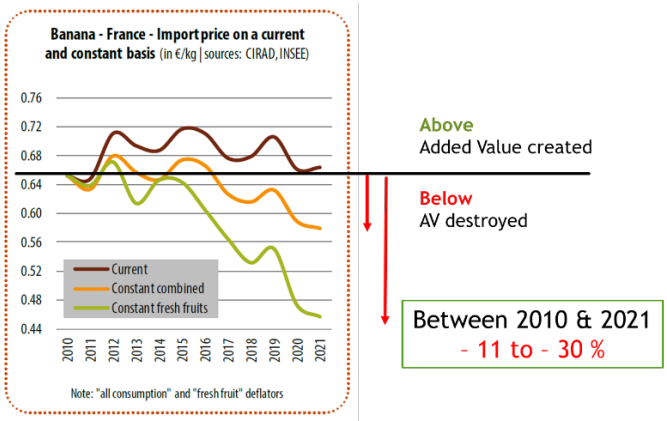
Especially since the different world markets are not all equal in the face of this influx of supply. Their receptivity is very different. Indeed, we note that a large part of this oversupply is intended, not for the entire world market, but first of all for "open" markets and especially for Europe and not at all for North America. In an open market, the result is a classic: the price drops in the face of an increase in supply.

Another reason for the fall in prices in Europe has been the deregulation of the European market which has played as a machine to destroy value. Recall that since 2010, the reduction of the customs duty for Dollar origins (from 176 euros / ton to 75 euros between 2010 and 2021) has "released" 3.5 billion euros for the eight origins that benefit from a lower duty. This is a lot of money that represents at the end of the process about 1.8 euros / carton. The problem is that this reduction in the duty has totally passed into the fall in price. Other factors (strong competition, oversupply) did the rest (about 1 euros). The depreciation of which we have already talked about 2.7 euros / carton.

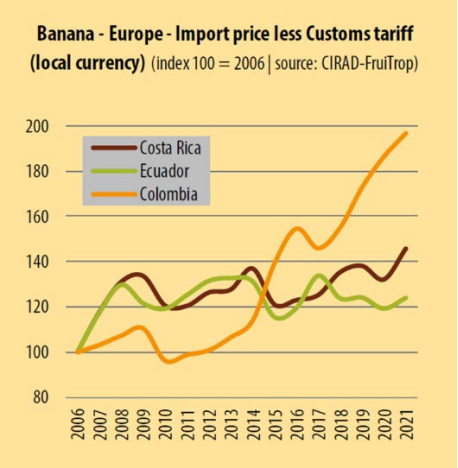
The conclusion is that the organized reduction of customs duties and therefore the liberalization of the market that have led to a strong movement of destruction of added value. We make the same observation for the organic banana or Fair-trade markets. A general and massive drop as can be seen here in the evolution of the prices of this range of products on the French market.



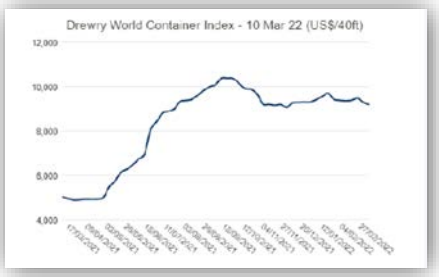
As the following graph shows, the French market has for example destroyed 30% of its value in a decade (comparison in constant euros evening taking into account inflation). To put it another way, the value of one kilogram of bananas compared to other fruits has lost 30% of its value in 10 years.

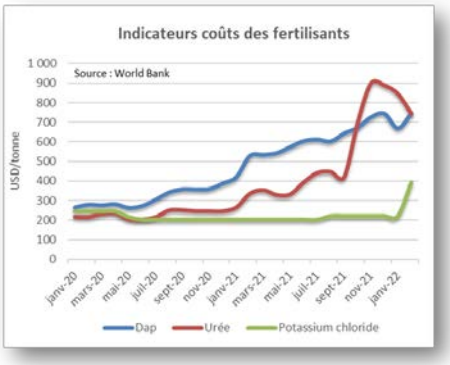


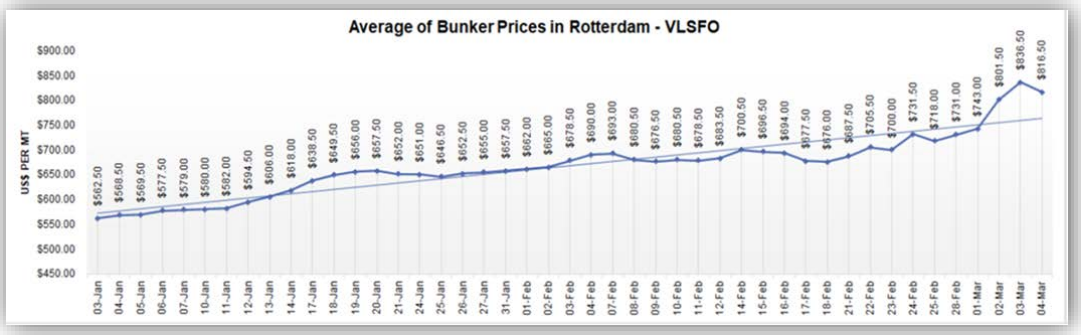
Another factor is the exchange rate, which has been very interesting for a very long time, particularly for Colombia. In this example, we can see that, all other things being equal, the value in Colombian peso has risen from an index of 100 in 2006 to nearly 200 in 2021. The result... about 85% of Colombia's exports go to Europe.



Other factors that reinforce the serious situation of the sector are the increase in production costs: fertilizers, freight, energy, cardboard, plastic, etc. The gap between the selling price and the cost of production becomes very difficult to hold even for origins considered ultra-competitive such as Ecuador.



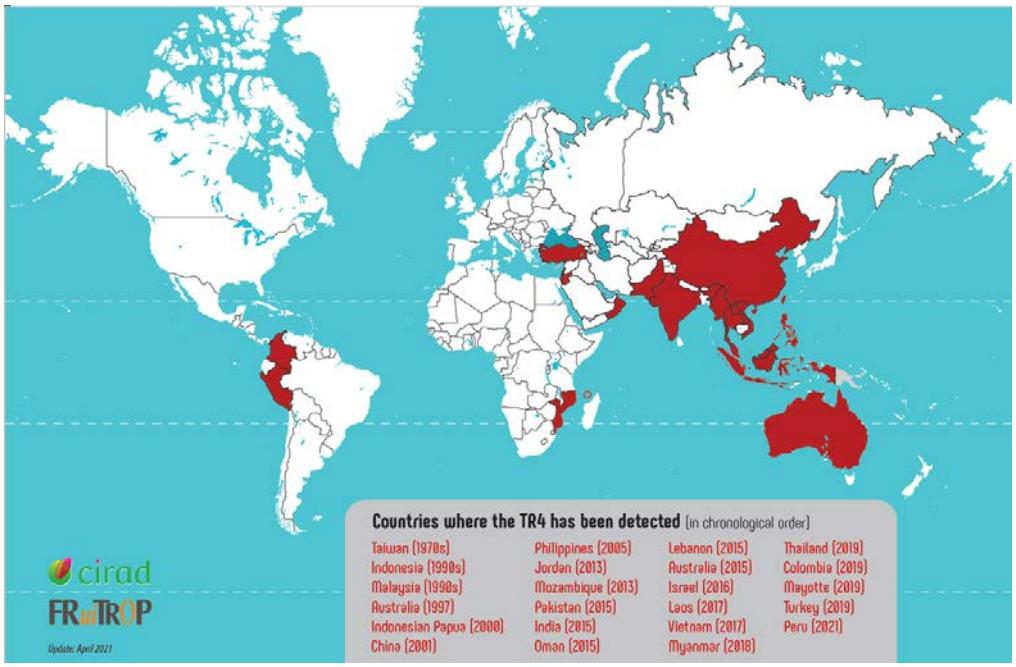




The increase in contract prices in Europe in 2022 is not enough to compensate for the increase in factors of production. Russia's invasion of Ukraine destabilized markets but had no heavy repercussions. It is the increase in the cost of production and the reduction of refrigerated freight capacity (availability, prices, congestion of ports, etc.) that has slowed down the influx of fruit in Europe, creating a tension on volumes and therefore on prices. But, the trend in spring 2022 is again negative on prices.

DISEASES AND PESTS

The purpose here is not to make an inventory of the diseases and pests that impact production systems. We just want to point out that the appearance of FUSARIUM TR4 in Colombia in 2019 and then in Peru in 2021 is a strong trauma for the banana world. The incurable nature of the disease requires control of its spread and therefore costly biocontrol measures. It is for the moment towards varietal improvement that all producers are turning to find a replacement variety for the Cavendish. CIRAD hybrids are also tested in an extensive network of countries to test their degree of resistance to TR4 but also to black sigatoka. In a second step (medium to long term), the tests in production and on the markets can begin within the framework of a public-private consortium: World Musa Alliance (WMA).



PUBLIC POLICIES

The influence of public policies ("hard law") on the banana sector is strong. It takes several forms but converges towards one goal: ever more sustainability.

Three examples for the same concept: everything converges towards a more sustainable European market:

1. The issue of Mancozeb with the reduction of the list of pesticides authorised in the EU;
2. Increasing national initiatives (Germany, UK, France, etc.) for greater sustainability in value chains... with the example of the *Sustainable Cocoa Initiative;*
3. The third example is linked to European concepts such as the Green Deal, the "From farm to fork" policy or the reciprocity of production rules (environmental and social) between local production and import rules (also called “mirror clauses”).

This will increase the constraints for suppliers in the value chain, but will also provide an opportunity to reform it and, perhaps, give arguments for reassessing prices.

The European authorities are also concerned about the level considered to be poor sustainability of this sector. As can be seen through this example on the "hidden costs" of a banana carton. In this example, two German institutions ABNB and GIZ published a study that estimates the gap between the cost of production and the sustainable cost at 6.7 USD/carton. The estimate is very complicated and probably more than approximate but the approach is very interesting. It should be recalled that over the last decade, 30% of the value added has been destroyed and that this type of study contributes to raising awareness in particular among supermarkets and intermediary operators.

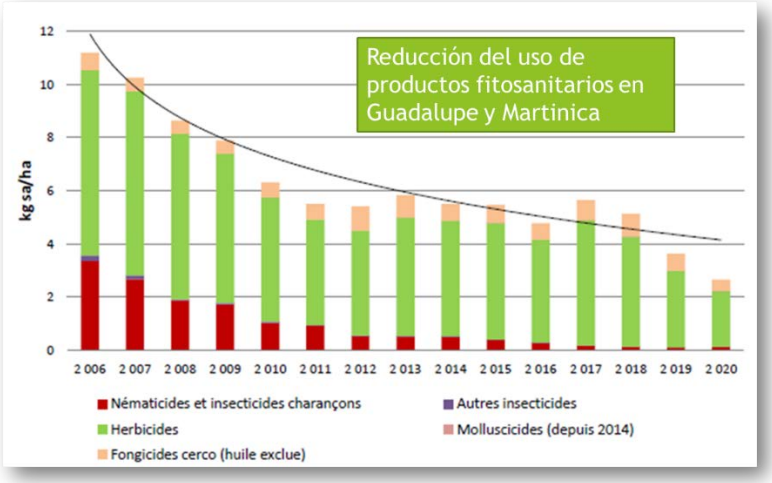
In addition to "Hard law", there is a "Soft law" dictated by the company's stakeholders (marketers, distributors, NGOs, certification body, consumer associations, citizens, etc.). Their concerns concern a wide range of social and environmental themes:

1. Pesticide reduction, pesticide residues
2. Carbon and water neutral, plastic-free
3. Working conditions, exposure of workers
4. Decent wages, distribution of value
5. Gender issues
6. Freedom of association
7. Etc.

This translates into certifications and distributor specifications that include these themes in the requirements required of their suppliers.

If we focus the analysis solely on phytosanitary aspects, we see that both European regulations and the restrictions imposed by supermarkets are shaping the future of the banana market. There is a lot of talk about the likely reduction in the maximum residue limit for mancozeb, but the restrictions affect all pesticide families: fungicides, insecticides, nematicides and herbicides. Reducing pesticide use is a major challenge for the banana industry.

The old "American" approach of having one or more cocktails of treatment products to control a disease or pest is a dead end. The French school offers a new approach. It advocates a systemic, integrated and holistic approach to problems: a mixture of agroecological techniques to promote biodiversity and thus improve and optimize biological balances. Fallow, trapping, leaf stripping, service plants, etc. techniques are offered. Combined and adapted to local specificities, these techniques have proven effective with a 70% reduction in pesticide use in Martinique and Guadeloupe. The same approach is being applied in Africa with very encouraging results.



This will also be done by combining changes in practices (agroecological approach) and increasing the biodiversity grown in banana plantations, starting with the use of varieties that are resistant or tolerant to the main threats, namely black sigatoka and FOC-R4T. This is the promise of the World Musa Alliance

(https://www.fruitrop.com/Articles-par-theme/Agronomie/2020/World-Musa-Alliance-version-en-espanol) initiative that CIRAD offers to all stakeholders around the world.

In **conclusion**, it can be said that another world of bananas is possible and that it will happen if operators become aware of the need to change the agronomic paradigm (agroecology and resistant varieties) and the economic paradigm through a better distribution of costs and benefits along the entire value chain, from the agricultural worker to the consumer. For this future to be possible, it is also necessary for the actors belonging to this value chain to participate in global R&D, which is the poor relation in the producing countries.

8. FUTURE IN R&D

8.1 PREVENTION FOC-TR4

- Introduction for trials : 3 Cirad hybrids (triploid AAA) resistant to FOC-TR4 & black Sigatoka : productivity evaluation and local consumption acceptance (only for local market !)
- 1 plot (Jarikaba & Nickerie) with 'RUBY' (MA13), tolerant to FOC-TR4

8.2. TRAINING

- Monitoring for BLSD
- Isolation of fungal populations for fungicide monitoring that could be done in Montpellier

8.3 RESEARCH & DEVELOPMENT

- Evaluation of agressiveness of Moko strains isolated in Jarikaba and Nickerie
- Experimentation of alternatives to pesticides : mass trapping for Black weevil, cover crops for herbicides, BS alternative strategies
- Exploration of intercropping systems : P&D management, multiple production, improvement of soil fertility
- Evaluation of new banana varieties

9. CONCLUSION

Moko disease is devastating wherever it has been observed: so it must be tackled with a serious and professional attitude, above all never lowering our guard! We need to understand that while in the medium term, **eradication of the disease is possible** by applying the recommendations provided, ***R. solanacearum*** **cannot be beaten** in industrial cultivation conditions, where irrigation and drainage systems provide a choice ecological niche for this organism (in the Netherlands, greenhouse producers have never been able to beat it, and to date some produce is still contaminated by cold strains of *R. solanacearum*).

As experts, we are well aware that all of our recommendations will have a heavy and long-term impact on the good agricultural practices already in place. It is up to the decision-making chain in the company to make it understood that team training is essential. Changes to habits, everyday repetitive actions, and how personnel enter and leave the plots, must be made as soon as possible. Two main arguments need to be disseminated within the company:

- ✓ It is only through this concerted effort by EVERYONE that Moko can be brought rapidly under control at Jarikaba, and the Nickerie plantation can be safeguarded.
- ✓ It is by virtue of this collective effort that any other banana disease, bacterial or otherwise, with a similar epidemiology, can also be prevented. This is part of a long-term perspective.

10. APPENDIX:

10.1. KNOWN HOST PLANT OF THE RSSC (SOURCE: EPPO)

Type	Scientific Name	References
Major host	*Arachis hypogaea*	* Cellier G, Prior P (2010) Deciphering phenotypic diversity of *Ralstonia solanacearum* strains pathogenic to potato. Phytopathology 100:1250-1261.
Major host	*Capsicum annuum*	* Abdurahman A, Parker ML, Kreuze J, Elphinstone JG, Struik PC, Kigundu A, Arengo E, Sharma K (2019) Molecular epidemiology of *Ralstonia solanacearum* Species Complex strains causing bacterial wilt of potato in Uganda. Phytopathology 109, 1922-1931 * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Ravelomanantsoa S, Robène I, Chiroleu F, Guérin F, Poussier S, Pruvost O, Prior P (2016). A novel multilocus variable number tandem repeat analysis typing scheme for African phylotype III strains of the *Ralstonia solanacearum* species complex. PeerJ. 4:e1949. doi: 10.7717/peerj.1949. * Santiago TR, Lopes CA, Caetano-Anollés G and Mizubutia ESG (2017) Phylotype and sequevar variability of *Ralstonia solanacearum* in Brazil, an ancient centre of diversity of the pathogen. Plant Pathology 66,383–392 * Thano P, Akarapisan A (2018) Phylotype and sequevar of *Ralstonia solanacearum* which causes bacterial wilt in Curcuma alismatifolia Gagnep. Letters in Applied Microbiolology 66: 384-393. https://doi.org/10.1111/lam.12857

Type	Scientific Name	References
Major host	*Musa sp.*	* Cellier G, Prior P (2010) Deciphering phenotypic diversity of *Ralstonia solanacearum* strains pathogenic to potato. Phytopathology 100:1250-1261. * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Pardo JM, López-Alvarez D, Ceballos G et al. (2019) Detection of *Ralstonia solanacearum* phylotype II, race 2 causing Moko disease and validation of genetic resistance observed in the hybrid plantain FHIA-21. Tropical Plant Pathology 44, 371–379 https://doi.org/10.1007/s40858-019-00282-3
Major host	*Musa x paradisiaca*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07 * Pardo JM, López-Alvarez D, Ceballos G et al. (2019) Detection of *Ralstonia solanacearum* phylotype II, race 2 causing Moko disease and validation of genetic resistance observed in the hybrid plantain FHIA-21. Tropical Plant Pathology 44, 371–379 https://doi.org/10.1007/s40858-019-00282-3
Major host	*Nicotiana tabacum*	* Abdurahman A, Parker ML, Kreuze J, Elphinstone JG, Struik PC, Kigundu A, Arengo E, Sharma K (2019) Molecular epidemiology of *Ralstonia solanacearum* Species Complex strains causing bacterial wilt of potato in Uganda. Phytopathology 109, 1922-1931 * Ravelomanantsoa S, Robène I, Chiroleu F, Guérin F, Poussier S, Pruvost O, Prior P (2016). A novel multilocus variable number tandem repeat analysis typing scheme for African phylotype III strains of the *Ralstonia solanacearum* species complex. PeerJ. 4:e1949. doi: 10.7717/peerj.1949. * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Rodrigues LMR, Destéfano SAL, Silva MJ, Costa GGL, Maringoni AC (2012) Characterization of *Ralstonia solanacearum* from Brazil using molecular methods and pathogenicity tests. Journal of Plant Pathology 94, 505–16.
Major host	*Solanum lycopersicum*	* Gutarra L, Herrera J, Fernandez E, Kreuze J, Lindqvist-Kreuze H (2017) Diversity, pathogenicity, and current occurrence of bacterial wilt bacterium *Ralstonia solanacearum* in Peru. Frontiers in Plant Science 8, 1221 DOI=10.3389/fpls.2017.01221 * Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102:924-936.

Type	Scientific Name	References
		* Mahbou Somo Toukam G, Cellier G, Wicker E, Guilbaud C, Kahane R, Allen C, Prior P (2009) Broad diversity of *Ralstonia solanacearum* strains in Cameroon. Plant Disease 93, 1123-1130 * N'Guessan CA, Abo K, Fondio L, Chiroleu F, Lebeau A, Poussier S, Wicker E, and Koné D (2012) So near and yet so far: the specific case of *Ralstonia solanacearum* populations from Côte d'Ivoire in Africa. Phytopathology 102, 733-740 * Poussier S, Prior P, Luisetti J, Hayward C, Fegan M (2000) Partial sequencing of the hrpB and endoglucanase genes confirms and expands the known diversity within the *Ralstonia solanacearum* Species Complex. Systematic and Applied Microbiology 23, 479-486 * Ramsubhag A, Lawrence D, Cassie D, Fraser R, Umaharan P, Prior P and Wicker E (2012) Wide genetic diversity of *Ralstonia solanacearum* strains affecting tomato in Trinidad, West Indies. Plant Pathology, 61: 844-857 * Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Major host	*Solanum melongena*	* Avinash P & Umesha S (2014) Identification and genetic diversity of bacterial wilt pathogen in brinjal. Archives of Phytopathology and Plant Protection, 47:4, 398-406. * N'Guessan CA, Abo K, Fondio L, Chiroleu F, Lebeau A, Poussier S, Wicker E, and Koné D (2012) So near and yet so far: the specific case of *Ralstonia solanacearum* populations from Côte d'Ivoire in Africa. Phytopathology 102, 733-740 * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374

Type	Scientific Name	References
Major host	*Solanum tuberosum*	* Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y * Gutarra L, Herrera J, Fernandez E, Kreuze J, Lindqvist-Kreuze H (2017) Diversity,pathogenicity, and current occurrence of bacterial wilt bacterium *Ralstonia solanacearum* in Peru. Frontiers in Plant Science 8, 1221 DOI=10.3389/fpls.2017.01221 * Mollae A, Hosseinipour A, Azadvar M, Massumi H, Ebrahimi F (2020) Phylotype and sequevar determination and AFLP fingerprinting of *Ralstonia solanacearum* strains causing bacterial wilt of potato in southeastern Iran. European Journal of Plant Pathology 157(6), 389–402. https://doi.org/10.1007/s10658-020-02018-5 * N'Guessan CA, Abo K, Fondio L, Chiroleu F, Lebeau A, Poussier S, Wicker E, and Koné D (2012) So near and yet so far: the specific case of *Ralstonia solanacearum* populations from Côte d'Ivoire in Africa. Phytopathology 102, 733-740 * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Ravelomanantsoa S, Robène I, Chiroleu F, Guérin F, Poussier S, Pruvost O, Prior P (2016) A novel multilocus variable number tandem repeat analysis typing scheme for African phylotype III strains of the *Ralstonia solanacearum* species complex. PeerJ. 4:e1949. doi: 10.7717/peerj.1949. * Rossato, M, Santiago TR, Mizubuti ESG, Lopes CA (2017) Characterization and pathogenicity to geranium of Brazilian strains of Ralstonia spp.. Tropical Plant Pathology 42, 458–467 * Santiago TR, Lopes CA, Caetano-Anollés G and Mizubutia ESG (2017) Phylotype and sequevar variability of *Ralstonia solanacearum* in Brazil, an ancient centre of diversity of the pathogen. Plant Pathology 66,383–392 * Wang L, Wang B, Zhao G, Cai X, Jabaji S, Seguin P, Chen H (2017) Genetic and pathogenic diversity of *Ralstonia solanacearum* causing potato brown rot in China. American Journal of Potato Research 94, 403–416. * Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Wild/Weed	*Bidens mitis*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among Ralstonia solanacearum strains isolated from the southeastern United States. Phytopathology 102:924-936.

Type	Scientific Name	References
Wild/Weed	*Bidens pilosa*	* Ravelomanantsoa S, Vernière C, Rieux A, Costet L, Chiroleu F, Arribat S, Cellier G, Pruvost O, Poussier S, Robène I, Guérin F, Prior P (2018) Molecular epidemiology of bacterial wilt in the Madagascar highlands caused by Andean (Phylotype IIB-1) and African (Phylotype III) brown rot strains of the *Ralstonia solanacearum* Species Complex. Frontiers in Plant Science 8, 2258
Wild/Weed	*Chenopodium album*	* Cruz L, Sousa-Santos M, Costa A & Carrinho H (2001) Present status of *Ralstonia solanacearum* in Portugal. In: Proceedings of the 11th Congress of the Mediterranean Phytopathological Union, Évora, Portugal, 252–254
Wild/Weed	*Cleome viscosa*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
Wild/Weed	*Coleus amboinicus*	* Deberdt P, Cellier G, Coranson-Beaudu R, Delmonteil--Girerd M, Canguio J and Rhino B (2021) First Report of Bacterial Wilt Caused by *Ralstonia solanacearum* on Plectranthus amboinicus in Martinique. Plant Disease 105(8), 2239. doi: 10.1094/PDIS-12-20-2622-PDN ------- confirmed host as Plectranthus amboinicus.
Wild/Weed	*Datura stramonium*	* Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y * Ustun N, Ozakman M, Karahan A (2009) Occurrence of *Ralstonia solanacearum* biovar 2 on tomato, weeds and irrigation water in Turkey. Acta Horticulturae. 808, 275-278
Wild/Weed	*Eleusine indica*	* Prieto Romo J, Gonzalo Morales OsorioI J, Salazar Yepes M (2012) Identification of new hosts for *Ralstonia solanacearum* (Smith) race 2 from Colombia. Revista de Protección Vegetal 27, 151-161
Wild/Weed	*Emilia sonchifolia*	* Obregón Barrios M, Rodríguez Gaviria PA, Gonzalo Morales Osorio J & Salazar Yepes M (2008) Hospedantes de *Ralstonia solanacearum* en plantaciones de banano y plátano en Colombia [Hosts of *Ralstonia solanacearum* on banana and plantain plantations in Colombia] Revista Facultad Nacional de Agronomía Medellín 61, 4518-4526
Wild/Weed	*Eupatorium cannabinum*	* Pradhanang PM, Elphinstone JG, Fox RTV (2000) Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. Plant Pathology, 49: 403-413.
Wild/Weed	*Galinsoga parviflora*	* Pradhanang PM, Elphinstone JG, Fox RTV (2000) Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. Plant Pathology, 49: 403-413. ------- natural host
Wild/Weed	*Galinsoga quadriradiata*	* Pradhanang PM, Elphinstone JG, Fox RTV (2000) Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. Plant Pathology, 49: 403-413. ------- natural host as G. ciliata.

Type	Scientific Name	References
Wild/Weed	*Gliricidia sepium*	* Prieto Romo J, Gonzalo Morales OsorioI J, Salazar Yepes M (2012) Identification of new hosts for *Ralstonia solanacearum* (Smith) race 2 from Colombia. Revista de Protección Vegetal 27, 151-161
Wild/Weed	*Hydrocotyle ranunculoides*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102:924-936.
Wild/Weed	*Marsypianthes chamaedrys*	* Rodrigues LMR, Destéfano SAL, Silva MJ, Costa GGL, Maringoni AC (2012) Characterization of *Ralstonia solanacearum* from Brazil using molecular methods and pathogenicity tests. Journal of Plant Pathology 94, 505–16.
Wild/Weed	*Oxalis sp.*	* Rodrigues LMR, Destéfano SAL, Silva MJ, Costa GGL, Maringoni AC (2012) Characterization of *Ralstonia solanacearum* from Brazil using molecular methods and pathogenicity tests. Journal of Plant Pathology 94, 505–16.
Wild/Weed	*Peperomia pellucida*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
Wild/Weed	*Persicaria capitata*	* Pradhanang PM, Elphinstone JG, Fox RTV (2000) Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. Plant Pathology, 49: 403-413.
Wild/Weed	*Persicaria pensylvanica*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among Ralstonia solanacearum strains isolated from the southeastern United States. Phytopathology 102:924-936.
Wild/Weed	*Physalis angulata*	* Swanepoel AE (1992) Survival of South African strains of biovar 2 and biovar 3 of Pseudomonas solanacearum in the roots and stems of weeds. Potato Research 55: 329-332
Wild/Weed	*Piper dilatatum*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
Wild/Weed	*Polygonum arenastrum*	* Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y
Wild/Weed	*Portulaca oleracea*	* Ustun N, Ozakman M, Karahan A (2009) Occurrence of *Ralstonia solanacearum* biovar 2 on tomato, weeds and irrigation water in Turkey. Acta Horticulturae. 808, 275-278
		* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
		* Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and

Type	Scientific Name	References
		environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y
Wild/Weed	*Senecio vulgaris*	* Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y
Wild/Weed	*Sesbania*	* Mahmud (1986); Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102:924-936.
Wild/Weed	*Solanum americanum*	* Sanchez Perez A, Mejia L, Fegan M, Allen C (2008) Diversity and distribution of *Ralstonia solanacearum* strains in Guatemala and rare occurrence of tomato fruit infection. Plant Pathology, 57: 320-331. https://doi.org/10.1111/j.1365-3059.2007.01769.x * Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Wild/Weed	*Solanum carolinense*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102:924-936. * Janse JD, van den Beld HE, Elphinstone J, Simpkins S, Tjou-Tam-Sin NNA, van Vaerenbergh J (2004) Introduction to Europe of *Ralstonia solanacearum* biovar 2 race 3 in Pelargonium zonale cuttings. Journal of Plant Pathology 86, 147-145
Wild/Weed	*Solanum cinereum*	* Janse JD, van den Beld HE, Elphinstone J, Simpkins S, Tjou-Tam-Sin NNA, van Vaerenbergh J (2004) Introduction to Europe of *Ralstonia solanacearum* biovar 2 race 3 in Pelargonium zonale cuttings. Journal of Plant Pathology 86, 147-145
Wild/Weed	*Solanum dulcamara*	* Persson P (1998) Successful eradication of *Ralstonia solanacearum* from Sweden. EPPO Bulletin, 28: 113-119. https://doi.org/10.1111/j.1365-2338.1998.tb00713.x * Wenneker M, Verdel M, Groeneveld R, Kempenaar C, van Beuningen AR, Janse JD (1999) Ralstonia (Pseudomonas) solanacearum Race 3 (Biovar 2) in surface water and natural weed hosts: first report on stinging nettle (Urtica dioica). European Journal of Plant Pathology 105, 307–315. * Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y; Parkinson et al. (2013)

Type	Scientific Name	References
Wild/Weed	*Solanum nigrum*	* Thano P, Akarapisan A (2018) Phylotype and sequevar of *Ralstonia solanacearum* which causes bacterial wilt in Curcuma alismatifolia Gagnep. Letters in Applied Microbiolology 66: 384-393. https://doi.org/10.1111/lam.12857 Safni et al. (2018) * Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y
Wild/Weed	*Solanum pseudocapsicum*	* Fernandez MC (1986) Some hosts of Pseudomonas solanacearum in Chile. (Algunos hospedantes de Pseudomonas solanacearum en Chile.) Agricultura Tecnica, Chile 46, 101-105 * Pradhanang PM, Elphinstone JG, Fox RTV (2000) Identification of crop and weed hosts of *Ralstonia solanacearum* biovar 2 in the hills of Nepal. Plant Pathology, 49: 403-413.
Wild/Weed	*Solanum sarrachoides*	* Fernandez MC (1986) Some hosts of Pseudomonas solanacearum in Chile. (Algunos hospedantes de Pseudomonas solanacearum en Chile.) Agricultura Tecnica, Chile 46, 101-105
Wild/Weed	*Solanum villosum*	* Janse JD, van den Beld HE, Elphinstone J, Simpkins S, Tjou-Tam-Sin NNA, van Vaerenbergh J (2004) Introduction to Europe of *Ralstonia solanacearum* biovar 2 race 3 in Pelargonium zonale cuttings. Journal of Plant Pathology 86, 147-145
Wild/Weed	*Solanum villosum subsp. miniatum*	* Ustun N, Ozakman M, Karahan A (2009) Occurrence of *Ralstonia solanacearum* biovar 2 on tomato, weeds and irrigation water in Turkey. Acta Horticulturae. 808, 275-278
Wild/Weed	*Soliva anthemifolia*	* Janse JD, van den Beld HE, Elphinstone J, Simpkins S, Tjou-Tam-Sin NNA, van Vaerenbergh J (2004) Introduction to Europe of *Ralstonia solanacearum* biovar 2 race 3 in Pelargonium zonale cuttings. Journal of Plant Pathology 86, 147-145
Wild/Weed	*Urtica urens*	* Wenneker M, Verdel M, Groeneveld R, Kempenaar C, van Beuningen AR, Janse JD (1999) Ralstonia (Pseudomonas) solanacearum Race 3 (Biovar 2) in surface water and natural weed hosts: first report on stinging nettle (Urtica dioica). European Journal of Plant Pathology 105, 307–315. * Cruz L, Eloy M, Quirino F, Oliveira H, Tenreiro R (2012) Molecular epidemiology of *Ralstonia solanacearum* strains from plants and environmental sources in Portugal. European Journal of Plant Pathology 133, 687–706 https://doi.org/10.1007/s10658-012-9947-y
Wild/Weed	*Xanthosoma sp.*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
Host	*Anthurium*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801.

Type	Scientific Name	References
		doi: 10.1128/AEM.00841-07 Cellier et al. (2012)
Host	*Canna indica*	* N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374
Host	*Capsicum pubescens*	* Gutarra L, Herrera J, Fernandez E, Kreuze J, Lindqvist-Kreuze H (2017) Diversity, pathogenicity, and current occurrence of bacterial wilt bacterium *Ralstonia solanacearum* in Peru. Frontiers in Plant Science 8, 1221 DOI=10.3389/fpls.2017.01221
Host	*Casuarina equisetifolia*	* Xu J, Pan ZC, Prior P, Xu JS, Zhang Z, Zhang H, Zhang LQ, He LY, Feng J (2009) Genetic diversity of *Ralstonia solanacearum* strains from China. European Journal of Pathology 125(4), 641-653.
Host	*Cichorium intybus*	* Lopes CA, Rossato M, Boiteux LS (2015) The Host status of Coffee (Coffea arabica) to *Ralstonia solanacearum* Phylotype I isolates. Tropical Plant Pathology 40, 1–4
Host	*Citrullus lanatus*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Cucumis melo*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Cucumis sativus*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Cucurbita maxima*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Cucurbita pepo*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Epipremnum pinnatum*	* Norman et al. (2009) Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi:

Type	Scientific Name	References
		10.1128/AEM.00841-07 Stulberg et al. (2015)
Host	*Eucalyptus*	* Alvarez Romero PI, Grabowski Ocampos C, Carpio C, Toro VS, Ferreira e Ferreira AFTA, Mizubuti ESG (2021) First report of *Ralstonia solanacearum* causing bacterial wilt of Eucalyptus in Ecuador. Plant Disease 105(1), p 211. * Carstensen GD, Venter SN, Wingfield MJ, Coutinho TA (2017) Two Ralstonia species associated with bacterial wilt of Eucalyptus. Plant Pathology 66(3), 393–403.
Host	*Heliconia*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102:924-936 * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Rodrigues LMR, Destéfano SAL, Silva MJ, Costa GGL, Maringoni AC (2012) Characterization of *Ralstonia solanacearum* from Brazil using molecular methods and pathogenicity tests. Journal of Plant Pathology 94, 505–16. Cellier & Prior (2010); Cellier et al. (2015) * Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Hydrangea macrophylla*	* Ji P, Allen C, Sanchez Perez A, Yao J, Elphinstone JG, Jones JB and Momol MT (2007) New diversity of *Ralstonia solanacearum* strains associated with vegetable and ornamental crops in Florida. Plant Disease 91:195-203.
Host	*Hydrangea paniculata*	* Ji P, Allen C, Sanchez Perez A, Yao J, Elphinstone JG, Jones JB and Momol MT (2007) New diversity of *Ralstonia solanacearum* strains associated with vegetable and ornamental crops in Florida. Plant Disease 91:195-203.
Host	*Hydrangea sp.*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among Ralstonia solanacearum strains isolated from the southeastern United States. Phytopathology 102:924-936.; Ji et al. (2007)
Host	*Impatiens*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D and Prior P (2009) Epidemiological evidence for the emergence of a new pathogenic variant of *Ralstonia solanacearum* in Martinique (French West Indies). Plant Pathology, 58: 853-861. https://doi.org/10.1111/j.1365-3059.2009.02098.x
Host	*Pandanus sp.*	* Wicker E, Grassart L, Coranson-Beaudu R, Mian D, Guilbaud C, Fegan M, Prior P (2007) *Ralstonia solanacearum* strains from Martinique (French West Indies) exhibiting a new pathogenic

Type	Scientific Name	References
		potential. Applied and Environmental Microbiology 73(21), 6790-801. doi: 10.1128/AEM.00841-07
Host	*Pelargonium*	* Hong JC, Norman DJ, Reed DL, Momol MT and Jones JB (2012) Diversity among *Ralstonia solanacearum* strains isolated from the southeastern United States. Phytopathology 102, 924-936. * N'Guessan CA, Brisse S, Le Roux-Nio A-C, Poussier S, Koné D, Wicker E (2013) Development of variable number of tandem repeats typing schemes for *Ralstonia solanacearum*, the agent of bacterial wilt, banana Moko disease and potato brown rot. Journal of Microbiological Methods 92, 366-374 * Rossato, M, Santiago TR, Mizubuti ESG, Lopes CA (2017) Characterization and pathogenicity to geranium of Brazilian strains of Ralstonia spp.. Tropical Plant Pathology 42, 458–467 * Janse JD, van den Beld HE, Elphinstone J, Simpkins S, Tjou-Tam-Sin NNA, van Vaerenbergh J (2004) Introduction to Europe of *Ralstonia solanacearum* biovar 2 race 3 in Pelargonium zonale cuttings. Journal of Plant Pathology 86, 147-145 * Ravelomanantsoa S, Robène I, Chiroleu F, Guérin F, Poussier S, Pruvost O, Prior P (2016) A novel multilocus variable number tandem repeat analysis typing scheme for African phylotype III strains of the *Ralstonia solanacearum* species complex. PeerJ. 4:e1949. doi: 10.7717/peerj.1949.
Host	*Pelargonium x hortorum*	* Ji P, Allen C, Sanchez Perez A, Yao J, Elphinstone JG, Jones JB and Momol MT (2007) New diversity of *Ralstonia solanacearum* strains associated with vegetable and ornamental crops in Florida. Plant Disease 91:195-203.
Host	*Phaseolus vulgaris*	* Ravelomanantsoa S, Vernière C, Rieux A, Costet L, Chiroleu F, Arribat S, Cellier G, Pruvost O, Poussier S, Robène I, Guérin F, Prior P (2018) Molecular epidemiology of bacterial wilt in the Madagascar highlands caused by Andean (Phylotype IIB-1) and African (Phylotype III) brown rot strains of the *Ralstonia solanacearum* Species Complex. Frontiers in Plant Science 8, 2258
Host	*Piper hispidum*	* Rossato, M, Santiago TR, Mizubuti ESG, Lopes CA (2017) Characterization and pathogenicity to geranium of Brazilian strains of Ralstonia spp.. Tropical Plant Pathology 42, 458–467 * Santiago TR, Lopes CA, Caetano-Anollés G and Mizubutia ESG (2017) Phylotype and sequevar variability of *Ralstonia solanacearum* in Brazil, an ancient centre of diversity of the pathogen. Plant Pathology 66,383–392
Host	*Psidium guajava*	* Prieto Romo J, Gonzalo Morales OsorioI J, Salazar Yepes M (2012) Identification of new hosts for *Ralstonia solanacearum* (Smith) race 2 from Colombia. Revista de Protección Vegetal 27, 151-161
Host	*Salpiglossis sinuata*	* Isson K (1976) Overwintering of Pseudomonas solana-cearum in Sweden. In: Sequeira L, Kelman A, eds. Proceedings of International Planning Conference Workshop onEcology and Control of Bacterial Wilt. Raleigh, NorthCarolina, USA: North Carolina State University, 105±9

Type	Scientific Name	References
Host	*Solanum aethiopicum*	* Rossato, M, Santiago TR, Mizubuti ESG, Lopes CA (2017) Characterization and pathogenicity to geranium of Brazilian strains of Ralstonia spp.. Tropical Plant Pathology 42, 458–467 * Santiago TR, Lopes CA, Caetano-Anollés G and Mizubutia ESG (2017) Phylotype and sequevar variability of *Ralstonia solanacearum* in Brazil, an ancient centre of diversity of the pathogen. Plant Pathology 66,383–392
Host	*Solanum betaceum*	* Martin C and Nydegger U (1982) Susceptibility of Cyphomandra betacea to Pseudomonas solanacearum. Plant Disease 66, 1025-1027
Host	*Solanum scabrum*	* Santiago TR, Lopes CA, Caetano-Anollés G and Mizubutia ESG (2017) Phylotype and sequevar variability of *Ralstonia solanacearum* in Brazil, an ancient centre of diversity of the pathogen. Plant Pathology 66,383–392
Host	*Tagetes*	* Rodrigues LMR, Destéfano SAL, Silva MJ, Costa GGL, Maringoni AC (2012) Characterization of *Ralstonia solanacearum* from Brazil using molecular methods and pathogenicity tests. Journal of Plant Pathology 94, 505–16.
Host	*Vaccinium corymbosum*	* Norman DJ, Bocsanczy AM, Harmon P, Harmon CL, Khan A (2018) First report of bacterial wilt disease caused by *Ralstonia solanacearum* on blueberries (Vaccinium corymbosum) in Florida. Plant Disease 102(2), p 438.

10.2. KNOWN HOST PLANT OF MOKO STRAINS (SOURCE: CABI)

Name	Family	Reference
Blechum pyramidatum (Browne's blechum)	Acanthaceae	Romo et al. (2012)
Capsicum (peppers)	*Solanaceae*	Romo et al. (2012)
Cissus verticillata (possum grape vine)	Vitaceae	Romo et al. (2012)
Colocasia esculenta (taro)	Araceae	Romo et al. (2012)
Commelina diffusa (spreading dayflower)	Commelinaceae	Romo et al. (2012)
Cucurbita maxima (giant pumpkin)	Cucurbitaceae	Romo et al. (2012)
Eleusine indica (goose grass)	Poaceae	Romo et al. (2012)
Eucalyptus grandis (saligna gum)	Myrtaceae	Alfenas et al. (2006)
Gliricidia sepium (gliricidia)	Fabaceae	Romo et al. (2012)
Heliconiaceae	Heliconiaceae	
Musa (banana)	Musaceae	Delgado et al. (2014);
Musa x paradisiaca (plantain)	Musaceae	Dzarifah et al. (2014)
Musaceae	Musaceae	
Oxalis latifolia (sorrel)	Oxalidaceae	Romo et al. (2012)
Piper (pepper)	Piperaceae	Romo et al. (2012)
Portulaca oleracea (purslane)	Portulacaceae	Romo et al. (2012)
Psidium guajava (guava)	Myrtaceae	Romo et al. (2012)
Solanum americanum	*Solanaceae*	Romo et al. (2012)
Solanum lycopersicum (tomato)	*Solanaceae*	Romo et al. (2012)
Solanum tuberosum (potato)	*Solanaceae*	Romo et al. (2012)
Musa textilis	Musaceae	Zehr, 1970; Eden Green, 1994a; Seal and Elphinstone, 1994; Taghavi et al., 1996

10.3. KNOWN HOST PLANT OF RSSC (BELALCAZAR ET AL., 2004)

Family	Genus	Species (Species in parentheses correspond to synonyms)
Acanthaceae	Barleria	B. lupulina Lindl.
	Ruellia	R. tuberosa L.
Amaranthaceae	Amarathus	A. graecizans L.
Apocyanoceae	Vinca	V. rosea L. (Lochnera rosea (L.) Reichb.)*
Asclepiadaceae	Asclepias	A. curassavica L.
Asteraceae	Clibadium	Clibadium sp.
	Hypochoeris	H. radicata L.
	Soliva	S. anthemidifolia
Balsaminaceae	Impatiens	I. balsamina L.
Boroginaceae	Heliotropium	H. indicum L.
Cannaceae	Canna	C. glauca L., C. Indica L.
Capparidaceae	Polanisia	P. viscosa (L.) DC.
Caryophyllaceae	Spergula	S. arvensis L.
	Silene	S. gallica L.
Casuarinaceae	Casuarina	C. equisetifolia Forst.
Cruciferae	Brassica	B. campestris L.
	Capsella	C. bursa-pastoris (L.) Moench.
Chenopodiaceae	Chenopodium	Ch. ambrosioides L.
		Ch. amaranticolor Coste et Reyn
		Ch. paniculatum L.
Chromolaeanaceae	Eupatorium	E. odoratum L.
Commelinaceae	Commelina	C. benghalensis L.
		C. difusa Burm. F.
		C. nudiflora L.
		C. longicaulis (Jacq.)
Compositae	Ageratum	A. conyzoides L.
	Ambrosia	A. artemisiifolia L., A. elatior L., A. trífida L.
	Aster	A. pilosus Willd.
	Bidens	B. bipinnata L., B. pilosa L.
	Blumea	B. balsamifera DC.
	Chrysanthemun	C. coronarium L., C. morifolium Ramat.
	Coreopsis	C. speciosa Hiern.
	Cosmos	C. bininnatus Cav.
	Dahlia	D. rosea Cav. (D. Pinnata Cav.)
	Eclipta	E. alba (L.) Hassk
	Eleutheranthera	E. ruderalis (Schw.) Sch. Bip.

Family	Genus	Species (Species in parentheses correspond to synonyms)
	Emilia	E. sonchifolia (L.) D.C.
	Erigeron	E. canadensis L. (Leptilon canadense (L.) Britt.)
	Eupatorium	E. odoratum L.
	Galisonga	G. parviflora Cav.
	Gerbera	Gerbera sp.
	Gnaphalium	G. elegans H.B.K.
	Gynura	G. crepidiodes Benth
Compositae (Cont.)	Helianthus	H. annuus L.
	Pluchea	P. indica Less.
	Senecio	S. sonchifolia Moench.
	Spilanthes	S. acmella Murr.
	Synedrella	S. nodiflora Gaertn
	Tagetes	T. erecta L., T. tenuifolia Cav. (T. signata Bartl). T. minuta L.
	Verbesina	V. alata L.
	Vernonia	V. chinensis Less.
	Xanthium	X. chinense Mill.
	Zinnia	Z. elegans Jacq.
Convolvulaceae	Merremia	M. hastata (Desr.) Hall.
		M. umbellata Hall.
		M. vitifolia (L.) Hall.
Euphorbiaceae	Acalypha	A. boehmerioides Miq.
	Aleurites	A. moluccana (L.) Willd.
	Croton	C. glandulosus L.
		C. glandulosus var. Septentrionalis M. Arg.
	Hevea	Hevea sp.
	Euphorbia	E. pilulifera L. (E. Hirta L.)
	Macaranga	M. tanarius (L.) M. Arg.
	Manihot	M. esculenta Crantz. (M. utilísima Pohl.)
		M. glaziovii M. Arg.
	Phyllanthus	P. niruri L., P. corcovadensis Muell.
	Ricinus	R. communis L.
Gesneriaceae	Erodium	E. moschatum L.
Labiatae	Dysophilla	D. auricularia (L.) Blume
	Salvia	S. privoides Benth.
Leguminosa	Agati	A. grandiflora Desv. (Sesbania grandiflora Pers.)
	Albizzia	A. falcata Back.
		A. hypogaea L. (A. nambyquarae Hoehne)
	Arachis	A. rasteiro A. Cheval

Family	Genus	Species (Species in parentheses correspond to synonyms)
	Canavallia	C. ensiformis DC.
	Cassia	C. mimosoides L. (C. leschenaultiana DC.)
	Cyamopsis	C. speciosus (sic)
	Indigofera	I. arrecta Hochst.
	Leucaena	L. glauca Benth.
	Mucuna	M. capitata W. & Arn.
	Phaseolus	P. calcaratus Roxb.
		P. coccineus L. (P. multiflorus Lam.)
		P. mungo L. (P. Radiatus L.)
		P. vulgaris L.
		P. vulgaris var. humulis (L.) Alef.
		(P. vulgaris var. nanus)
	Tephrosia	T. vogellii Hook
	Voandzeia	V. subterranean Thou.
Loganiaceae	Spigelia	. anthelmia L.
Malghiaceae	Thyrallis	T. glauca Kuntze
		(Galphimia gracilis Bartl.)
Malvaceae	Hibiscus	H. cannabinus L., H. sabdariffa L.
	Urena	U. lobata L.
Martyniaceae	Proboscidea	P. louisianica (Mill.) Thell.
		(Martynia proboscidea Glox.)
		(M. Louisiana Mill.)
Musaceae	Heliconia	H. acuminata A. Rich.
		H. caribaea Lam.
		H. imbricata Baker
		H. latisphata Benth.
		H. psittacorum L.
	Musa	M. nana Lour. (M. cavendishii Lamb.)
		M. ensete J.F. Gmel.
		M. paradisiacal L.
		M. sapientum L.
		M. textilis Nee
Pedaliaceae	Sesamum	S. indicum L. (S. orientale L.)
Phytolaccaceae	Phytolacca	P. octandra L.
Piperaceae	Piper	P. auritum H.B.K.
		P. peltatum L
Polygalaceae	Polygala	P. paniculata L.
Polygonaceae	Rumex	R. abyssinicus Jacq., R.crispux L.

Family	Genus	Species (Species in parentheses correspond to synonyms)
		R. acetosella L., R. sajittatus Thunb.
		R. obtusifolius L.
Portulacaceae	Talium	T. racemosum Rohrb.
Scrophulariaceae	Scoparia	S. dulcis L.
Solanaceae	Atropa	A. belladona L.
	Browalia	B. americana L. (B. demissa L.)
	Capsicum	C. frutescens L.
		(C. annum L., C. baccatum L.)
		C. frutescens var. longum (L.) Bailey
		(C. longum DC.)
		Cyphomandra
		C. betacea Sendt.
	Datura	D. metel L. (D. fastuosa L.,
		(D. cornucopia Hort.)
		D. meteloides Dunal)
		D. stramonium L.
		D. stramonium var. tatula (L.) Torr.
		(D. tatula L.)
	Hyoscyamus	H. níger L.
	Lycopersicon	L. esculentum Mill.
		(L. lycopersicon (L.) Kast.)
		L. esculentum var. pyriforme (Mill.) Alef.
		L. esculentum var. cerasiforme (Mill.) Alef.
		(L. cerasiforme Dunal)
		L. pimpinellifolium Mill.
	Nicotiana	N. acuminata (Grah.) Hook
		N. olata Link & Otto
		N. olata var. Grandiflora (Otto) Comes
		(N. affinis Moore)
		N. atropurpurea (sic)
		N. atropurpurea var. grandiflora (sic)
		N. attenuata S. Wats.
		N. caesia Suksd.
		N. cavanillesii Dun
		N. debneyi Domin.
		N. exigua H.M. Wheeler
		N. glauca Grah.
		N. glutinosa L.

Family	Genus	Species (Species in parentheses correspond to synonyms)
		N. goodspeedii H.M. Wheeler
		N. gossei Domin.
		N. langsdorfii Schrank
		N. latissima (Mill.) DC.
		N. longiflora Cav.
		N. macrophylla Lehm.
		N. maritima H.M. Wheeler
		N. megalosiphon Heurck. & Muell. Arg.
		N. miersii Remy.
		N. nesophila Johnst.
		N. nudicaulis S. Wats.
		N. paniculata L.
		N. plumbaginifolia Viv.
		N. quadrivalvis Pursh.
		N. raimondii MacBride
		N. repanda Willd.
		N. rotundifolia Lindl.
		N. rustica L.
		N. sanderae Hort.
		N. sylvestris Speg. & Comes
		N. stocktoni Brandegee
		N. suaveolens Lehm.,
		N. tabacum L.
		N. tomentosa Ruiz & Pav.
		(N. colossea Andr.)
		N. trigonophylla Dun.
		N. triplex Kost.
	Petunia	P. híbrida Vilm
	Physalis	P. alkekengi L.
		P. angulata L.
		P. crassifolia Benth
		P. peruviana L.
		P. pruinosa L.
		P. philadelphica Lam.
	Salpiglossis	S. sinuata Ruiz & Pav.
	Schizanthus	S. pinnatus Ruiz & Pav.
	Solanum	S. aculeatissimum Jacq.
		S. andigenum Juz. & Buk.

Family	Genus	Species (Species in parentheses correspond to synonyms)
		S. antipoviczii Buk.
		S. caldasii Humb. & Bonpl.
		S. caripense H.B.K
		S. carolinense L.
		S. chocoense Bitter
		S. citrifolium A.Br.
		S. commersoni Dun.
		S. demissum Lindl.
		S. ferox L.
		S. hirtum Vahl.
		S. integrifolium Poir
		S. macrocarpum L.
		S. mammosum L.
		S. melongena L.
		S melongena var. Breviolaceum L.
		S. near panduraeforme (sic)
		S. nigrum L., (S. caribaeum Dunal)
		S. nodiflorum Jacq.
		S. pyracanthum Jacq.
		S. quitoense Lam.
		S. sucrense Hawkes
		S. sysymbrii Lam.
		S. torvum Sev
		S. tuberosum L.
		S. umbellatum L.
		S. verbascifolium L.
Sterculiaceae	Abrama	A. augusta L.
Strelitziaceae	Strelitzia	S. reginae Banks.
Tiliaceae	Corchorus	C. acutangulus Lam.
Tropaeolaceae	Tropaeolum	T. labbianum Hort.
		T. majus L.
		T. majus var. nanum (L.) Vilm.
		T. minus L.
		T. peregrinum L.
Ulmaceae	Trema	T. amboinensis Blumme
Urticaceae	Fleurya	F. interrupta Gaud.
	Pilea	P. hyalina L.
	Pouzolzia	Pouzolzia sp.

Family	Genus	Species (Species in parentheses correspond to synonyms)
Verbenaceae	Callicarpa	C. tomentosa (L.) Murr.
	Lantana	L. camara var. aculeata (L.) Mohl
		(L. aculeata L.)
		L. trifolia L.
	Stachytarpheta	S. indica (L.) Vahl
	Tectona	T. grandis L.
	Verbena	V. brasiliensis Vell.
		V. erinoides Lam.
		V. hybrida Voss.
Zingiberaceae	Zingiber	Z. officinale Rosc.

10.4. ADDITIONNAL KNOWN HOST PLANT OF RSSC (BELALCAZAR ET AL., 2004)

Scientific Name	Common name (Spanish)	Publication
Anacardium oocidentale	Marañón	Shiomi *et al*, 1989
Anthurium sp.	Anturium	Norman and Yuen, 1999
Arabidopsis thaliana		Yang and Ho, 1998
Archontophoenix alexandrae		Akiew and Hams, 1990
Brassica campestri L.	Nabo	Belalcázar, Uribe y Thurston, 1968
Capsella bursa-pastoris (L.) Moench	Pan y Quesito	Belalcázar, Uribe y Thurston, 1968
Casuarina equisetifolia Forst.	Pino falso	Orian, G., citado Buddenhagen y Kelman, 1964
Cecropia peltata		Berg, 1971
Clibadium sp.		Buddenhagen, 1960
Cucumis sativus		Horita and Tsuchiya, 2000
Cucurbita maxima x c. Moschata		Horita and Tsuchiya, 2000
Cyphomandra betacea	Tomate de árbol	Martín *et al*, 1982
Chenopodium amaranticolor C.-R.	Cenizo rojo	Belalcázar, Uribe y Thurston, 1968
Chenopodium paniculatum L .	Cenizo	Belalcázar, Uribe y Thurston, 1968
Datua ferox		Aklew and Hans, 1990
Emilia sonchifolia (L.) D.C.	Lechuguilla	Granada, 1996
Erodium moschatum L.	Alfileres	Belalcázar, Uribe y Thurston, 1968
Eucalyptus spp.	Eucalipto	Dianese *et al*, 1990
Eupatorium odoratum L.	Guaco, falso guaco	Sequeira and Averre, 1961
Fragaria vesca	Fresa	Goto *et al*, 1978
Galisonga parviflora Cav.	Guasca	Belalcázar, Uribe y Thurston, 1968
Gnaphalium elegans H.B.K.	Lanilla	Belalcázar, Uribe y Thurston, 1968
Heliconia acuminata Rich	Sororoquinha	Sequeira and Averre, 1960, 1961
Heliconia caribaea Lam.	Plátano cimarrón	Buddenhagen, 1960
Heliconia imbricata Baker		Sequeira and Averre, 1960, 1961
Heliconia latispatha Benth	Bihao	Sequeira and Averre, 1960, 1961
Heliconia psittacorum L.	Platanillo	Quinon, Aragaki and Ishii, 1964
Hedychium sp.	Ginger	Aragaki and Quinon, 1965
Hevea sp.	Caucho	Wiersum, citado Buddenhagen y Kelman, 1964
Hypochoeris radicata L.	Diente de León	Belalcázar, Uribe y Thurston, 1968
Kalanchoe sp.		Horita and Tsuchiya, 2000
Lagasca mollis		Kishun *et al*, 1982
Limonium sp.		Horita and Tsuchiya, 2000
Morus sp.		Horita and Tsuchiya, 2000

Scientific Name	Common name (Spanish)	Publication
Musa textiles Nee.	Abacá	Waite, 1954
Pelargonium capitatum	Geranio	Horita and Tsuchiya, 2000
Phyllantus corcovadensis Muell.	Balsilla	Granada, 1996
Physalis pubescens L.		Buddenhagen, 1960
Pilea hyalina		Granada, 1996
Piper auritum H.B.K.		Berg, 1971
Piper peltatum L.		Berg, 1971
Portulaca oleraceae		Quimio and Chan, 1979
Ranunculus scleratus		Sunaina *et al*, 1989
Rumex acetosella L.	Sangre de Toro	Belalcázar, Uribe y Thurston, 1968
Rumex obtusifolius L.	Barrabás	Belalcázar, Uribe y Thurston, 1968
Rumex crispux L.	Lenguavaca	Belalcázar, Uribe y Thurston, 1968
Silene gallica L.	Cascabelitos	Belalcázar, Uribe y Thurston, 1968
Solanum caripense L.	Llorones	Belalcázar, Uribe y Thurston, 1968
Solanum cinereum		Graham and Lloyd, 1978
Solanum hirtum Vahl.		Berg, 1971
Solanarum dulcamara		Olsson, 1976
Solanum nodiflorum Jacq.		Buddenhagen, Quinon and Aragaki, 1963
Solanum umbellatum Mill.		Berg, 1971
Soliva anthemidifolis R.Br.		Belalcázar, Uribe y Thurston, 1968
Spergula arvensis L.	Abrojito	Belalcázar, Uribe y Thurston, 1968
Strelitzia reginae Banks.		Quinon and Aragaki, 1963
Stylosanthes humilis		Aldrick, 1971
Tagetes minuta L.		Dukes, Morton and Jenkis, 1965
Verbena brasiliensis Vell.	Verbena	Belalcázar, Uribe y Thurston, 1968
Xanthosomas roseum Schott.		Berg, 1971
Zingiber officinale Rosc.	Ajenjible, ginger	Ishii and Aragaki, 1963

10.5. KNOWN HOST PLANT OF MOKO STRAINS (BELALCAZAR ET AL., 2004)

Scientific Name	**Common name (Spanish)**
Ageratum conyzoides L.	Manrubio
Ambrosia artemisiifolia L.	Artemisa
Asclepias curassavica L.	Algondoncillo
Bidens cynapiifolia H.B.K.	Cadillo
Bidens pilosa L.	Papunga
Browalia americana L.	Zulia, verbena azul
Canna glauca L.	Chirilla
Commelina difusa Burm. F.	Canutillo
Croton hirtus (L.) Herit.	Tostoncillo
Emilia sonchifolia (L.) D.C.	Lechugilla
Euphorbia hirta L.	Canchalagua
Galinsoga parviflora Cav.	Guasca
Ipatiens balsamina L.	Besitos
Lantana camara L.	Venturosa
Lantana trifolia L.	Filigrana
Physalis angulata L.	Uchuva
Phyllanthus corcovadensis Muell	Balsilla
Phyllanthus niruri L.	Viernes santo
Pilea hyalina L.	
Polygala paniculata L.	Ipecacuana
Rumex cryspus L.	Barrabas, Lengua de vaca
Scoparia dulsis L.	Arrocillo
Solanum nigrum Sendt.	Hierba mora
Spilanthes acmella L.	Botoncillo
Synedrella nodiflora (L.) Gaertn	Cerbatana
Verbena litoralis H.B.K.	Verbena

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