ENDURE

European Network for Durable Exploitation of crop protection strategies

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Thematic Priority 5
FOOD and Quality and Safety

DR1.14 BANANA: Projects dealing with one or several identified gaps of knowledge for reduction of pesticides in bananas

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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)	
Dissemination Level	
PU Public	**X**
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

ANR : Agence Nationale de la Recherche (French national Agency for Research)

ASPROCAN: Asociación de Productores de Plátano de Canarias (Spain)

Banana CS: Banana Case Study in NoE ENDURE

BLSD : Black Leaf Streak Disease

CARBAP: Centre Africain de Recherches sur les Bananiers et Plantains

CIRAD: Centre de Coopération Internationale en Recherche agronomique pour le Développement

ENDURE: European Network for Durable Exploitation of crop protection strategies

ICIA: Instituto Canario de Investigaciones Agrarias

UGPBAN: Union des Groupements de Producteurs de Bananes des Antilles françaises

Summary

Two proposals of research projects dealing with gaps of knowledge for pesticide reduction in bananas were elaborated.

The first one called MOSAIC – a Systerra project planned to be funded by ANR the French national Agency for Research) - is entitled “analysis and Modelling of spatial Organization of cropping systems on Spreading And Integrated Control of crop-pests - design of generic tools for zero pesticide systems engineering”. Deposited a first time in 2008 at ANR by CIRAD, it was received in waiting list. This project was consequently reformatted, completed, and re-submitted to the ANR in 2009. In case of non acceptance, the identified gaps of knowledge and the ways to tackle them will be considered in other call for projects.

A second research project, entitled: “Fungicide resistance management of *M. fijiensis*, causal agent of Black Sigatoka of bananas - Investigations on fungicide resistance development and its possible reversibility by specific management strategies” which is an ATF (French National cooperation) project gathering CARBAP, Bayer Crop science and CIRAD, was accepted.

In addition, two development projects integrating alternative and innovative management strategies among those identified in DR1.16 to reduce pesticide use in bananas were recently presented and accepted. The first one called BIOMUSA is led by ICIA (Canary, Spain) and the banana grower association of the transnational region Spain and Portugal (Canary Islands, Madeira, Azores). The other called “Plan Banane Durable” in led by CIRAD and the banana grower association of the French West Indies (France). Both address knowledge and know-how transfer along with validation of innovating solutions to reduce pesticides in bananas, in the framework of a participative approach with banana growers.

The targeted gaps of knowledge and transfer/validation of identified solutions that were treated in DR1.14 are of interest for any banana producing countries desirous to develop innovations to lessen pesticide use in bananas.

Teams involved:
CIRAD
CARBAP
ICIA

Geographical areas covered:
France (French West Indies)
Spain (Canaries)
Portugal (Madeira and Azores)
Cameroon
Additionally, it must be precised that any banana producing country tackling pesticide reduction and friendly-environmentally practices, can be interested by the gaps of knowledge targeted in this deliverable

Degree of validation and operability of findings:
Deposited, or recently launched projects.

1- Research Project 1: MOSAIC Project: "Analysis and Modelling of spatial and temporal Organisation of cropping systems on Spreading And Integrated Control of crop-pests: Design of generic tools for zero pesticide systems engineering"

1.1. Involved partners

This French national project is planned to be leaded by CIRAD (UPR 26) which is a member of the ENDURE Banana CS. It should involve different French research teams among which some are members of the ENDURE network.

Partners are:

- CIRAD
  - UPR 26 Martinique
  - UMR PVBMT Reunion
  - UR27 Martinique
- INRA
  - UR PSH Avignon
  - UMR Santé Végétale Bordeaux
  - UERI Gotheron
- Agro-Paris-Tech
  - UMR Agronomie
  - USC 1285 Ecologie
- IRD
  - UMR RPB Martinique

1.2 Background

The MOSAIC project was built in the framework of the national priority in France to reduce pesticide use by promoting innovative cropping practices and strategies. This was underlined, for instance, by the "Grenelle de l'environnement" (Plan EcoPhyto 2018) and the recent program « *Objectif terres 2020: Pour un nouveau modèle agricole français* » from the French ministry of agriculture and fisheries.

The MOSAIC project deals with different model plants among which Banana is a major tropical crop. The project has been deposited in last April 2009 at the French national Agency for Research in the framework of a national call for projects entitled "Systerra". Yet deposited a first time in 2008, it was received in waiting list. If it is accepted this time, it will run on 2009-2012 (4 years). In case of non acceptance, the project will be further completed and re-deposited on 2010 to allow bridging the addressed gaps of knowledge.

1.3 Targeted gaps of knowledge

Cropping systems designed for export bananas are generally characterized by large-scale monocultures exhibiting a poor landscape fragmentation and a strong spatial, temporal and genetic homogeneity of the plant cover. In such cropping systems, proliferation of pests and diseases is generally significant. As a consequence, to sustain productivity, growers have frequently recourse to external inputs such as frequent sprayings of fungicides, herbicides, nematicides

and other pesticides to restrict the spread and the impact of air- or soil-borne pathogens on banana crops. Such strategies have as well economic as environmental significant costs.

To define substitutes or alternatives for reducing agrochemical use in bananas different options are being implemented by researchers, growers and other stakeholders. They have been reviewed in the framework of DR 1.16, and can be consulted at:http://www.endure-network.eu/about_endure/all_the_news/new_guides_for_better_banana_production

To further establish and strengthen the ecological bases of an innovative agriculture for bananas, it is now critical to study in particular how the effects of variation in spatial and temporal arrangements of the plant cover organization influence the importance and efficacy of natural biological regulations. This includes a better understanding of the effects of mixed cropping, intercropping and other cultural practices based on vegetation management strategies, as well on pests and diseases, as on natural enemies of banana pests. This is a poorly documented investigation field that requires to be tackled for developing agroecological and environmentally friendly approaches for decreasing pesticide use in bananas. Figure 1 depicts the main research questions tackled in the framework of the MOSAIC project.

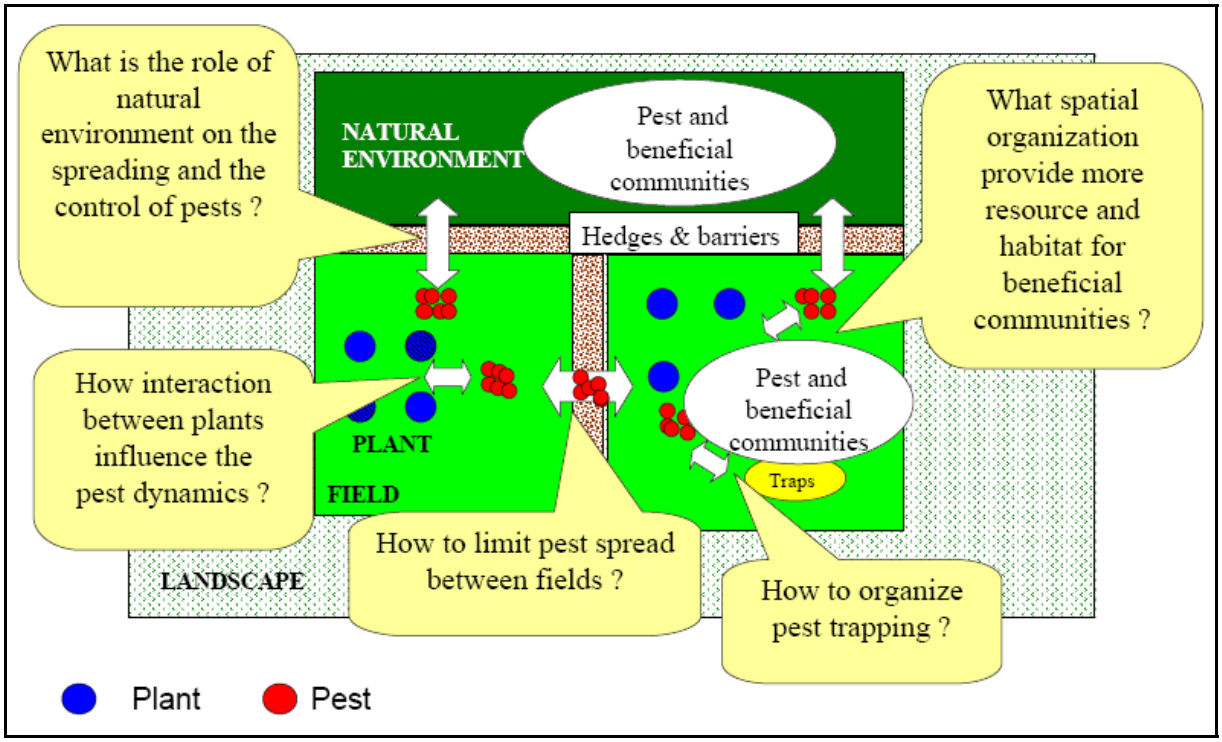

Figure 1: Scientific questions treated in MOSAIC Project

1.4. Objectives

From a cognitive point of view, the main objective of MOSAIC project is to develop relevant knowledge, methods and decision tools for designing as well in tropical as in temperate regions, innovative agrosystems that rely on optimized

crop arrangements in space and in time, at the plot and the landscape scales, in order to alleviate plant pathogens, pests (including weeds) and their impacts, without excessive agrochemical use.

To ensure genericity MOSAIC project deals with:

- A selected range of couples of pests (or diseases) and cropping systems covering most of spreading or regulation modes of crop pests. Two types of tropical crops (bananas, market gardening) and three types of temperate crops (oil seed rape, grape and orchards) are considered.

- the designing of new conceptual frameworks at the crossroad of agronomy and ecology, such as the study of food webs in which interact pests or plant pathogens and their natural enemies, and the regulation of these food webs.

- The use of simulation models to describe pests and pathogens dynamics regarding to the vegetation arrangement in and between cropped fields.

From a more applied point of view, the objectives of MOSAIC project are to define innovative generic scenarios for crop organization, at different time and space scales, to restrict use of pesticides. These scenarios will directly contribute to the **development of cropping systems relying on integrated crop management and biological control methods**.

1.5 Brief state of the art

To implement pest and disease control while reducing pesticide use in crops, different non-chemical approaches can be implemented: use of resistant varieties, development of biological control methods, managing of crop diseases through specific cultural practices (Lewis et al., 1997). Among these, the increase of plant and animal biodiversity present in the agrosystem (through the use of cover crops, mixed cropping, intercropping, the setting of hedgerows, shelterbelts, windbreaks, the use of predators, the promotion of soil health through development of useful macro and microfauna, …) is pointed out as a natural and sustainable means to strengthen biological regulations leading to alleviation of disease and pest pressure (Altieri, 1999; Moonen and Barberi, 2008). Crop arrangement at the field and at the landscape scales is a critical action lever to ensure ecological services such as pest and disease regulations (Ponti et al., 2007).

1.6 Planned tasks

The project is made of five main tasks:

. Task 0 is devoted to the coordination and the animation of the project.

. Task 1 focuses on the effects of vegetation arrangements on pest or pathogen spread and biological regulations. This task also deals with the relationships between population abundance of crop pests or inocula, and that of their corresponding predators or biological control agents. Intra plot and landscape scales are considered.

. Task 2 has to target the multi scale modelling of biological regulations. Increasing the value of data obtained in task 1, simulation models of population dynamics will be designed for crop pests with respect to different vegetation arrangements. The spatial epidemiology will be modelled for crop pests and their natural enemies (bottom-up regulations). Trophic webs will be characterized and modelled (top town regulations), and multi scaling models for the epidemiology of these crop pests and their ecological regulation will be designed.

. Task 3 will test various scenarios for the designing of **innovative cropping systems**. Based on the knowledge integrated in the models of Task 2, different spatial organizations allowing restricting pesticide use will be established. They will allow evaluating the most promising prototypes in relation with different stakeholders (researchers, extension officers, farmers). Agronomical, economical and environmental criteria will be considered.

. Task 4 is designed to increase the value of the obtained results through publications, meetings with the implied stakeholders, and training sessions for farmers.

1.7 Added value of the MOSAIC project

The MOSAIC project will rely on:

- ✓ An approach focusing on a promising but still poorly experienced concept, that of ecological intensification. In particular, spatial arrangement of the plant cover, associated with an increase of biodiversity will be evaluated as a functional means to promote sustainability.

- ✓ A multi disciplinary analysis of the determinism of crop pest regulation through vegetation re arrangements. Such an approach brings together agronomists, ecologues, plant pathologists, statisticians, modellers from different research instates and from as well tropical as temperate geographic regions.

- ✓ A modelling approach combining different spatial and temporal scales.

- ✓ Integration of knowledge in predictive models that allow describing the complexity of crop pest dynamics in relation with their biological regulations.

- ✓ A selected choice of couples of pest/cropping system to encompass as well a representative range of pest spreading modes, as a diversified set of tropical or temperate crops, to ensure genericity of the approach.

- ✓ Research teams implied in different national and international networks, including ENDURE itself. To come up end user expectations, and make easier result transfers, they will interact with producers, as early as the programme planning of researches.

1.8. Cited bibliography

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2- Research Project 2 "Fungicide resistance management of *M. fijiensis*, causal agent of Black Sigatoka of bananas - Investigations on fungicide resistance development and its possible reversibility by specific management strategies"

2.1 Involved partners

This project gathers as well 2 research partners of the ENDURE Banana Case Study i.e. CARBAP (Cameroon) and CIRAD (UPR 26, UMR BGPI, France), as an industrial partner which is Bayer Crop science. This project is supported by ASSOBACAM, the main banana grower association of Cameroon. It was deposited at the ATF (French National cooperation between France and Cameroon), and was accepted. It will run on 3 years (2008-2010).

2.2 Background

Black Leaf Streak Disease (BLSD) is a worldwide foliar disease that consistently hampers production, not only in intensive banana cropping systems, but also in smallholder fields (Jones, 2000). Its causal agent, the ascomycete fungus *Mycosphaerella fijiensis* drastically reduces the plant photosynthetic activity while, what leads to yield losses varying from 10 to 100%.

Because of the build up of resistance to systemic fungicides in *M. fijiensis* populations (mainly DMIs and Strobilurins), the use of these fungicide types was heavily restricted or stopped in last years. Following the decline of systemic fungicide use for controlling BLSD, decrease in the level of resistance was nevertheless registered in some banana cropping systems, such as for instance in Cameroon.

2.3 Targeted gaps of knowledge

It is unknown whether such an evolution is effective and lasting, and whether resistance to systemic fungicides could be reversible, thus giving the possibility to reintroduce systemic fungicides while substantially reducing amounts and doses of contact fungicides in the framework of a well fitted

forecasting system. In addition, the underlying mechanisms of such a possible reversion are not studied, although their knowledge could validly contribute to a more sustainable use of pesticides for controlling *M. fijiensis* throughout the world.

2.4. Objectives

The main objectives of the current project are to evaluate the possible reversibility of fungicide resistance (with new resistance management strategies) in *M. fijiensis* populations, in order to restore an acceptable level of sensibility in intensive banana agrosystems, and reintroduce a forecasting control strategy using systemic fungicides. Characteristics of the targeted fungicides are given in figure 2.

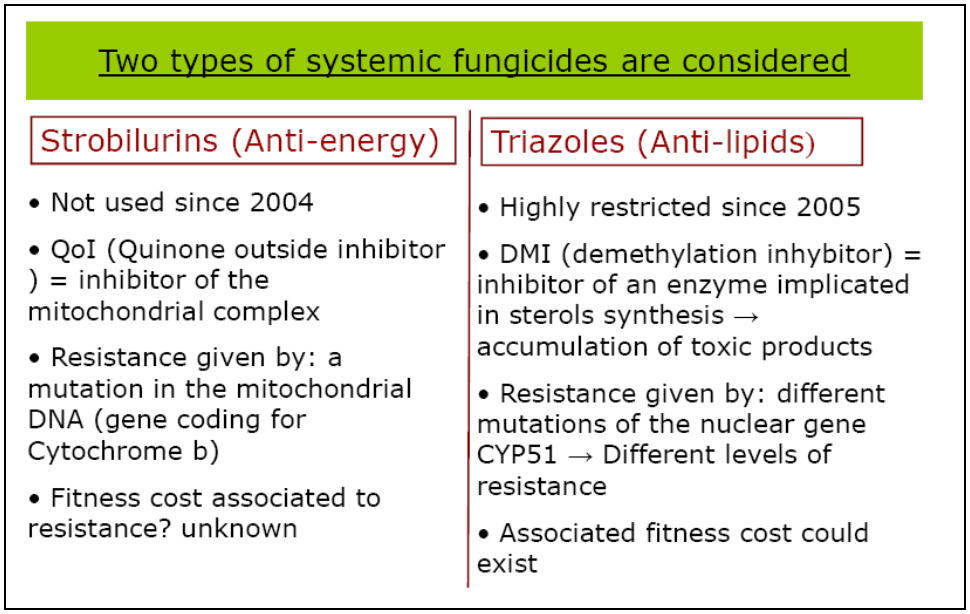

Figure 2: Characteristics of the targeted fungicides

2.5 Brief state of the art

At the end of the eighties, a forecasting system relying on biological descriptors of the disease, and use of systemic fungicides was proposed, and used in some banana producing countries such as Cameroon. This strategy allowed controlling BLSD with 12-14 yearly fungicide sprays instead of the 40-45 sprays required with preventive sprayings of contact fungicides. Unfortunately after some years, mismanagement of the disease (including misapplications of the forecasting system and repeated sprays of systemic fungicides) led to the build up of resistance to systemic fungicides in *M. fijiensis populations* (de Lapeyre de Bellaire *et al.*, 2009). As a consequence, control strategies were reorganized through weekly sprays of contact fungicides. Although these ones did not allow resistant fungal strains to arise, they drastically increased the economic and environmental costs of BLSD control strategies, since that beyond the 40-45 sprays they relied on, much more important dose rates must be applied with them than with systemic fungicides.

Recent monitoring data obtained in Cameroon, showed that some years after cessation of systemic fungicide sprays, there were fluctuations in resistance levels to these fungicides (Propiconazole, Strobilurins…) in *M. fijiensis* populations. This took place, as well in time, as in space. These phenomena are potentially linked to some degree of resistance reversion. Such reversion cases have already been reported for other ascomycete fruit pathogens (Koller et al., 1991; Cox et al., 2007). Nevertheless the underlying mechanisms are still misunderstood, although their better knowledge could contribute to highlight how such instability of resistance to systemic fungicide in *M. fijiensis* could be successfully be exploited for building up alternative management of this widespread banana pathogen.

2.6 Planned tasks

It was hypothesised that the evolution of resistance to systemic fungicides in *M. fijiensis* populations depends on the interactions between gene flow (sprayed areas vs. unsprayed ones), selection exerted by fungicides, and possibly counter-selection of resistant fungal genotypes. This led to the design of two main tasks:

. Task a is devoted to an accurate monitoring of the evolution of resistance to systemic fungicides in the intensive banana cropping systems of Cameroon.

. Task b has the objective to:

- unravel the mechanisms involved in the evolution of fungicide resistance through an analysis of gene flow and dispersal parameters of *M. fijiensis* at the agrosystem scale (field studies and modelling process of field data).
- better explicit selection and counter selection parameters (including fitness) through field experimentations and artificial inoculations.

2.7. Cited bibliography

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3-Additional development projects integrating alternative and innovative options identified in DR 1.16 to reduce pesticides in bananas

Technical solutions yet identified to bridge gaps of knowledge for a sustainable reduction in pesticide use that were selected in the deliverable DR

1.16 of the Banana CS were also integrated for further validation in two recently accepted development projects involving the two bigger European regions producing bananas: Respectively, the MAC region i.e. Madeira + Azores + Canaries (Portugal and Spain) which is implied in the project "BIOMUSA", and, the French West Indies, which are involved in the project "Plan banane durable". Defined with the central contribution of two members of the Banana CS, respectively, ICIA (Spain), and CIRAD (France), these two projects similarly imply banana growers, researchers and other stakeholders dealing with pesticide reduction and more sustainable banana cropping systems.

For the MAC region, the transnational project BIOMUSA ("Sustainable development of banana crop in the outer most regions MAC", Interreg IV program, 2009-2013) has the objective to transfer innovating results from banana research programs, and to promote their development with the help of banana growers desirous to implement more sustainable banana cropping systems. This project, which is being launched, also plans to build up a multidisciplinary platform to support implementation of environmentally friendly and productive banana cropping systems. Partners of BIOMUSA project are:

- ICIA; ASPROCAN: The banana grower association of Canaries (Spain); University of La Laguna (Canaries, Spain).
- Regional secretariat of the Environment and Natural Resources - Regional Management for Agriculture and rural development (Madeira, Portugal).
- University of Azores (Madeira, Portugal).

For the French West Indies, the project "Plan banane durable" is also completed by an Interreg IV program (2009-2013). Supported by a national funding, this project is aimed at reducing the environmental impact of banana cropping systems in the French West Indies, through the deployment of innovating strategies relying less on pesticides. Figures 3 and 4 respectively depict the main objectives, and operational components of the "Plan banane durable".

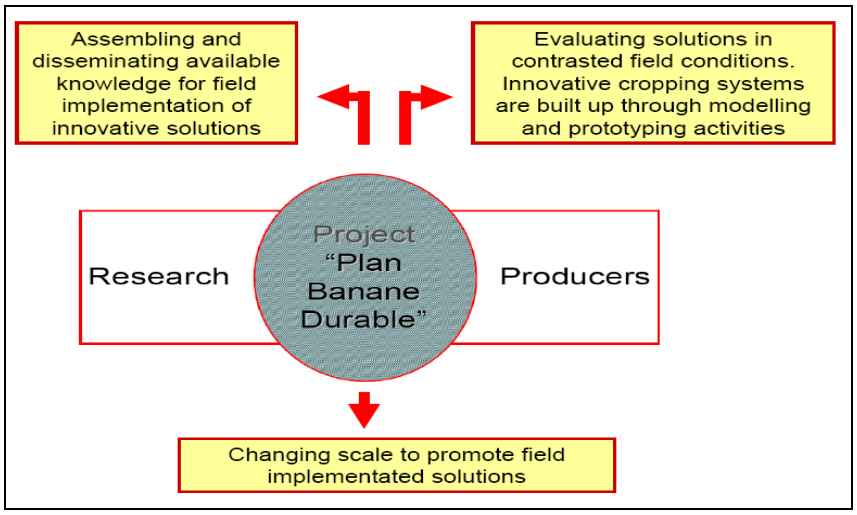

Figure 3: Objectives of the French project "Plan Banane Durable"

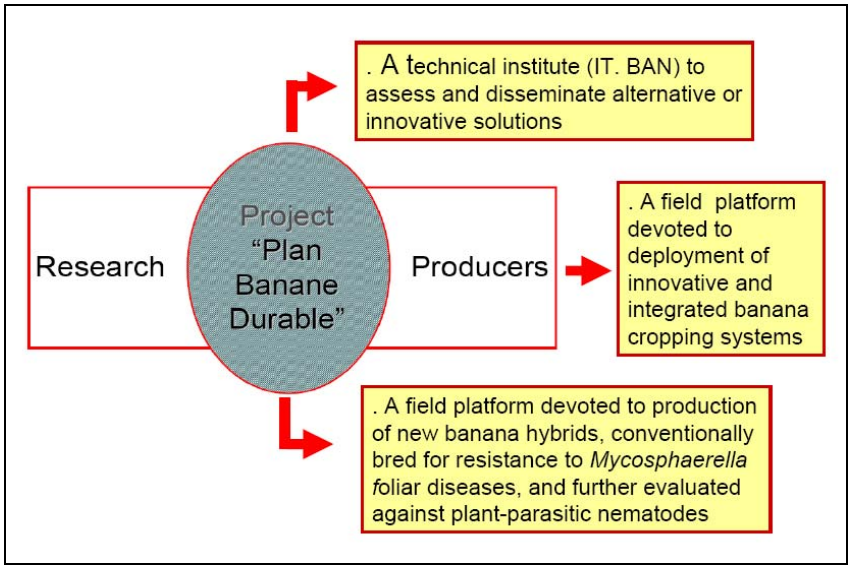

Figure 4: The three main operational components of the project "Plan Banane durable"

This project has also the double following ambition to:

. Speed up and ensure innovation transfer to the growers.

. Validate, as well from a technical as from an economical point of view the transferred innovation.

Consequently, the project takes place in the framework of a participative approach with banana grower associations. It has been launched since 6 months.

4- Conclusion

An important benefit to attribute to this ENDURE deliverable DR1.14 is that it has allowed scientific people searching for innovative ways to reduce pesticides in bananas, to meet, to exchange, to consolidate theirs links, and finally to define project proposals addressing gaps of knowledge.

The studied gaps of knowledge focus on: i/ the effects of variation in spatial and temporal arrangements of the plant cover organization on the importance and efficacy of natural biological regulations with a particular attention of the case of bananas, a major tropical crop. ii/the reversibility of fungicide resistance (mainly to DMIs and Strobilurins) in *M. fijiensis* populations, a worldwide and threatening fungal pathogen of bananas.

Thus, two research proposals dealing with these scientific gaps of knowledge were built up by some of the partners of the Banana CS. The first project has been proposed to the French Research Agency ANR; the second one is accepted, and is going on.

In addition, two other development projects addressing this time, technical knowledge to transfer and validate were also proposed and accepted. Implying

the grower associations of the two bigger European banana producers, they constitute an original participative approach to speed up innovation transfer and settle bases of new banana cropping systems that are less dependent upon pesticides.

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