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8	Figures 9 and 10 emended to Figures 11 and 12, respectively, in text and legend	17
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Introduction

Formation and capacitation of farmers and agricultural workers have been identified as crucial needs to develop robust agricultural productive systems in Cuba. In particular, formation activities are required when converting from conventional, chemical agriculture towards new, agroecological approaches (Díaz, 2015). It is worth to consider that many people have been incorporated in food production in the country, without previous experience in farm/crop management.

The agricultural production in Cuba has been developed with the coexistence of different types of land property and productive forms. Actually, the majority of farmers and agricultural workers have a middle/high education levels (*see results of survey in D9.1*), and all can read and write properly.

In Cuba, the dissemination of information and the farmers capacity building for crops/pest management are made in different ways, by using: printed or electronic materials (manuals, books, leaflets, cards); TV/radio information; courses; *in situ* experiments during projects or during under- and post-graduate students activities (practices and thesis), as well as through the technical assistance provided by governmental (Agriculture Ministry, Research Centers, Universities) and non-governmental (National Small Farmers Association (Asociación Nacional de Agricultores Pequeños, ANAP) and Cuban Association of Agricultural and Forest Technicians-ACTAF) stakeholders.

1. Methods used in Field Farming Schools (FFS) activities

The FFS methodology has been adapted to the characteristics of Cuba and was developed by ANAP. It is called "From Farmer to Farmer Movement" (F to F) and was, at the beginning, a methodology to promote ecologic agriculture. According to Cárdenas (2003), the farmers capacity building is a transformation process to improve the farmers work and develop the use of local alternatives to resolve their farming problems.

The "*F to F*" education model recommended in Cuba is a "Process Focusing Model", with the objective of promoting the farmers' "*think*", and is based on a *teaching-learning process*. The individual farmer or groups need to identify their needs, the causes of the problems in farming/cropping. Some types of SWOT analysis (at the farm/crop/pest level) have to be done, to achieve the identified goals. To obtain all these informations, the farmer or group must hence be allowed to "*think*".

Some type of activities and methodological tools in "From Farmer to Farmer Movement" were described by Cárdenas (2003) (Table 1). Additionally, Díaz (2015) suggested methods such as the use (by farmer) of individual adviser or supervisors (promoters, extension service personal or researchers/professors), field days, workshops, conferences to technicians, fairs, leaflets, local or regional radio and television, videos and local or national press. Background information at CENSA, based on previous projects work, suggest that activities such as systematic walks and interchanges with farmers and technicians, field days, and experiments programmed/developed with farmers, are important to create a confident environment between farmers and researches.

Table 1. Activities and methodological tools developed by the "From Farmer to Farmer Movement" (Cárdenas, 2003).

Activities	Methodological Tools
Rapid diagnostics	Activities in owned farms
Inventory of experiences and promoters	Didactic shows
Interchanges among farmers groups	Techniques, plays, poetry, theater plays, for children and adults
Promoters' interchanges (zones)	Videos
Promoters' interchanges (municipal, provinces and national levels)	Radio broadcastings
Capacitation journeys	Drawings and pictures
Interchange tours	Power Point Presentations
Field days	
Small scale experiments in fields	
Technical and methodological workshops	
Visit to farmers	

Based on all the elements of the "*F to F*" indications and the results of previous surveys, the MUSA team designed and developed a number of activities. The survey provided the team the informations about the '*what'*, '*who'*, '*how'* and '*why'* concerning farms and farmers (their characteristics, expectation, crop/pest management, etc.). These informations (below summarized in Table 2) allowed the preparation of actions to implement "*F to F*" activities in banana/plantain pest management.

Table 2. The informations collected for the "*F to F*" activities in banana/plantain pest management.

What…	Is the scholar level of farmers ? Are the problems that farmers have with banana/plantain crops ? Is the banana/plantain cultivar more frequently used by farmers ? Are the most important pests causing damage to banana/plantain crops in the farm ? Type of activities do the farmer prefer in learning processes ? Plants (botanic products) do they use for pest management ?
Who…	Are the farmers' leaders? (in order to select them as promoters and carry out some demostrative experiments in farms or governmental productive zone). Are the farmers that recognized (or use) endophytes and biocontrol agents (EBCAs) for banana/plantain pest management? Which farmers do apply IPM?
How…	Farmers obtain and prepare banana/plantain "seeds"? Farmers perform pest management? The MUSA team may perform capacitation? Using printed materials, conferences, talk, etc. ?
Why…	Farmers do not get risk perception about some pest? Farmers use EBCAs or do not? Farmers do not use IPM?

Some problems were detected in the previous survey (*D9.1*) such as: lack of knowledge about principal pests of banana/plantain in Cuba conditions. Moreover, farmers need more information and instructions for use and application of EBCAs and about the problems they may have for IPM and biocontrol.

2. Activities of MUSA team

Preparation, edition and distribution of leaflets with different topics such as EBCAs, plant parasitic nematodes (PPN) and banana weevil (BW); seminars; conferences with phytosanitary technicians; technical demonstrations in private farms and governmental areas; work with pre- and post graduate students; news in radio broadcasts, or video in local or national TV programs; trainings (for MUSA personnel in Cuba and other countries), workshops and courses.

Some changes and modifications caused by special conditions to limit Covid-19 risks included conferences in PPT/PDF format and incorporated in institutional webpages (www.censa.edu.cu). The conferences and leaflets were distribute using WhatsApp to groups and e-mails towards students (final year of Agronomy Faculty at Havana Agrarian University, UNAH). PhD students belonging to the National PhD Program of Plant Health, coordinated by the UNESCO Agroecology Cathedra (UNAH) were involved in practical activities with farmers.

2.1 Summary of activities

The CENSA team identified leader farmers and two governmental areas for work as experimental locations: one agricultural production area and the *National Musa Collection*.

The field experiments selected as demonstration areas, were:

1) a governmental area in Nueva Paz Municipality (Mayabeque province), with productive banana/plantain enterprises. The MUSA team visited the areas, presented the objectives of the project and selected, with the corresponding directives, the area for the experiments. The assays with most effective results obtained in this enterprise were generalized in the province (Fig .1).

Figure 1. Presentation of MUSA project to directives and technicians at Nueva Paz (A). Selection of the area for experiments in coordination with the director of Nueva Paz enterprise (B). Field experiment established in Nueva Paz to locally probe the action of EBCAs on nematode populations, crop development and production (C, D).

2) The *National Musa Collection* was identified as a hot spot for work in MUSA, because it is the largest collection in the country. The collection is located and managed by the National Tuber, Banana/Plantain Research Institute (INIVIT), and is located in the central province of Villa Clara. INIVIT is in charge of the collection custody and is responsible for the banana/plantain breeding program in Cuba. Any positive experience in their areas may be replicated in other parts of the country.

The work in this location started with meetings at INIVIT with directives to present the MUSA project, and for selection of 22 genotypes for survey. *Musa* spp. roots, soil and weeds surveys were carried out and analyzed at the nematology lab. at CENSA. Accordingly, following the results and other data from the Project, some changes were suggested for PPN and weevils (BW) management. All of them were studied/proposed to directives and agricultural workers and performed in the creation of new parcels for the *Musa* spp. collection.

Actually, the renovated *Musa* spp. collection is showing good plant conditions, and is followed by the MUSA team well after Project end. EBCAs have been used for PPN and other pest management. This site represents a demonstrative area for management of major crops pests and diseases (Fig. 2).

Some farmers were selected for work as leader farmers, i.e. eng. J.F. Hernández[1], owner of farm in Guira (Melena Municipality, Artemisa Province). Eng. Hernández is an enthusiast of entomopathogenic nematodes (EPN) use and of other EBCAs. He actually develops its MSc. thesis on EPN and *Bacillus thuringiensis* for management of *Plutella xyllostella* in cabbage.

Figure 2. Images from the old (left) and renovated (Oct. 2020, right) *Musa* spp., collection at INIVIT. The seeds for the new collection were treated with hot water and EBCAs as pest preventive measures.

Mr. Y. Hernández[2] is leader in the use of agroecological pest management tools in San José de las Lajas Municipality. His farm entered the conversion phase (from traditional to agroecological management) more than 10 years ago. This farmer adopts the use of EPN, *Trichoderma asperellum* and cultural practices for pest management. His family is integrating farm work with gender movement initiatives in this municipality. Mr. Hernández and his wife attended the MUSA meeting in Cuba, due to their interest in MUSA results (Fig. 3).

Figure 3. Eng. J. F. Hernández and other workers (A) and visit of MUSA team in 2019 to "El Mulato" farm in Mayabeque, with owner Mr. Y. Hernández.

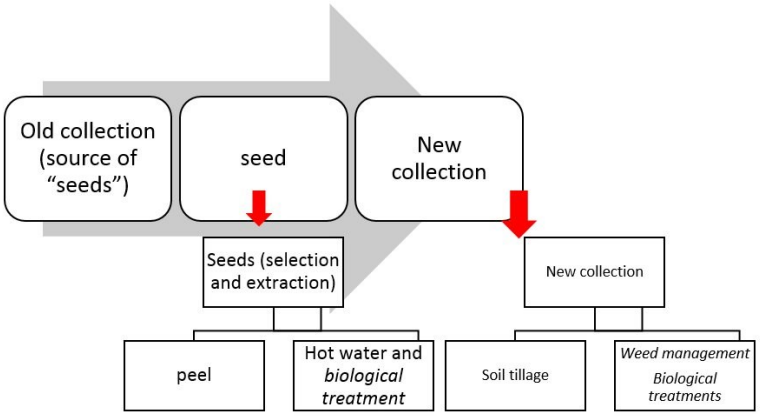
[1] Informed consent provided

[2] Informed consent provided.

2.1.1 Description of MUSA results disseminated through the field farming schools

For Germoplasm bank (INIVIT)

Since beginning of July 2020 a new National Banana/plantain Collection has been planted in INIVIT (Villa Clara Province, Cuba). By indications of the MUSA Team, some tactics have been implemented in order to decrease the negative impacts of BW and PPN on genotypes. Some recommended tactics indicated by the Cuban MUSA Team are shown (*italics*).



Process to establish new *Musa* spp. collection at INIVIT, Cuba.

Seed oblation: Selection of 6 suckers per each accessions. Extracting the rhizomes and eliminating those severely affected by nematodes or weevils. Cutting (peeling) and putting the rhizomes selected for each accession in a plastic bag or net. Introducing the bag in boiling water taking into account the rhizome caliber and weight (Fig. 4A).

Treating corms with Cuban strains of mycorrhiza and EBCAs, according to type of soil in INIVT (Fig. 4B). The mycorrhizal product proceeds from National Institute of Agricultural Science (INCA), with high quality standard. The inoculum must be prepared as liquid solution: 100 L of water + 25 kg of solid product (25%). The peeled corms in the plastic net are submerged for 20 sec and then let to dry, before use for plantation (Fig. 4C).

Fig. 4. Activities to establish the new *Musa* spp. National Collection at INIVIT in July 2020. A) Selection of planting material, peel corms ("*mondado*") and boiling water treatment. B) Treatment with Cuban mycorrhizae, *Trichoderma asperellum* and *Pochonia chlamydosporia*. C) Plantation.

For new plantations

In Cuba, the propagation material for banana/plantain crops has two source: *vitro-plants*, proceeding from biotechnology laboratories, and *corms*. The source preference depends mostly on the type of productive characteristics of farms (mainly private sector) or enterprises (estate sector). In case of corms, they can be used for seedling production in so-called Seed Accelerated Reproduction Center (CRAS), in pre-germination or nursery areas, or may be directly used in plantations (D6.2).

If the seeds come from biotechnological laboratories, they are free of BW and PPN. The farmers can use them in new plantations with no risks. The banana and plantain seedlings obtained in biotechnological laboratories are also treated, in the acclimatization phase, with the EBCAs *P. chlamydosporia* (commercial product KlamiC®) and *T. asperellum*.

Vitroplants: previous treatment with EBCAs

Application	*T. asperellum* (concentration)	*P. chlamydosporia* (concentration)
To substrates (in 0.5 t)	1,5 kg (10^9 CFU g^{-1})	1,5 kg (10^7 CFU g^{-1})
To plants, 1 week before transplant *(drench)*	50 ml (10^7 CFU ml^{-1})	50 ml (10^5 CFU ml^{-1})

If the farmer cannot use the vitroplants and must rely on corms or seedling from CRAS or directly from plantations, then it is recommended to apply EBCAs as follows: at plantation, *T. asperellum* (strain Ta 13.) and *P. chlamydosporia* var. *catenulata* (IMI SD 187, KlamiC) appled in holes, one week before planting the seed.

Application	*T. asperellum* (conc.)	*P. chlamydosporia* (conc.)
In plantation hole	100 ml (10^9 CFU g^{-1}) it is convenient and necessary to apply if *Fusarium oxysporum* f. sp. *cubense* (Foc) is present.	30 g (10^7 CFU g^{-1})

After plantation:

Application	frequency	dose (conc.)	localization
T. asperellum	Every 6 months	100-200 ml (10^7 CFU g^{-1})	In suckers area
P. chlamydosporia	Every 3 month	100-200 ml (10^7 CFU g^{-1})	In suckers area

Traps evaluated for BW monitoring in MUSA (D6.1) (Fig. 5)

Modified disk trap: made by cutting the base of pseudostem at height of 15 cm, then cut in the form of grids and covered with leaves, until the time of observation.

Pseudostem wedge-type trap: made by cutting fractions of the wedge-shaped pseudostem, leaves are placed between one fraction and another to facilitate the BW entry.

Stump or base trap modified (TDM, modified disk trap)

Pseudostem wedge-type trap (TTC)

Figure 5. "*Pseudotallo*" and strump traps used in BW monitoring.

Additional information provided to farmers

Entomopathogenic nematodes: Product BionemC, a.i. *Heterorhabditis amazonensis* strain HC1 (Number in GenBank KU870321). ***Methodology for use****:* application with standard equipment to foliage and soil, it is also suitable to manage Lepidoptera, Coleoptera, Hemiptera and other insects. Compatible with *Lecanicillum lecanii* and *Beauveria bassiana*, and bio-nutrient (registered in Cuba such as FitomaS-E®). ***Formulation and application***: bag with 5 million of IJ. Use at dose of 100 000 IJ/m^2 o higher, in aqueous solution. ***How can farmers obtain the product?*** In the country more than 30 CREE produce *H. amazonensis*.

Another disseminated knowledge was the elimination of alternative hosts of *Meloidogyne.* The susceptible host weed *Commelina diffusa* was reported for the first time from Cuba during the MUSA activities. This report was disseminated through the FFS and Bulletins for producers, with photographs of galled roots. In addition, another 62 species of weeds were described as alternative hosts of the four main genera of phytoparasitic nematodes that affect plantain and banana crops.

Demonstrations

These technologies were demonstrated during FFS at the field and provincial biotechnological laboratory levels:

- The use of acclimatization areas at the Mayabeque biofactory.
- The role of plantain and national banana germplasm banks at INIVIT, Villa Clara.
- The plantation areas in Nueva Paz, Mayabeque Province.

2.1.2 How the uncertainty on effectiveness of IPM practices was communicated

Uncertainty and risks were communicated during all training activities. It is well known that the success of the application (technical efficiency and economic feasibility) of IPM tactics depends on various factors. Among these, first of all, the level of knowledge of producers stands out. This is not a problem in Cuba, due to the relatively high educational level of farmers, an aspect analyzed in the socio-economic study carried out in MUSA (D9.1).

However, other factors related to the farm characteristics also contribute to the success of the IPM applications disseminated. For these reasons it was always suggested that IPM-related decisions must be contextualized and adapted to the characteristics of each scenario. This concept is even more important when talking about biological control, where with living organisms are involved. In the case of MUSA this concerned EPN and fungi.

Among the aspects mentioned above, for example, the following were considered:

- *Timing of EBCAs applications*: they should be applied either early in the morning or late in the afternoon, to avoid the effect of sunlight (UV) and high temperatures that affect the microorganisms reproduction, metabolism and functioning.
- *Irrigation*: humidity benefits the activity of EBCAs.
- *Use of chemical pesticides*: they can affect the colonization and survival of EBCAs, it is recommended only the use of those for which compatibility was demonstrated, an aspect analyzed in MUSA and reported in the methodology described (D9.1).
- *EBCAs compatibility*: this aspect is also described in the methodology (D9.1). *Pochonia chlamydosporia* var. *catenulata*, *Trichoderma asperellum* and mycorrhizae (INCAM 11 strain) are compatible.
- *Intrinsic soil characteristics*: it is especially important to characterize the soil type in the scenario where EBCAs are applied, because factors such as pH are important for microorganisms. The strains proposed for IPM in MUSA were characterized from the physiological point of view and there is knowledge on the pH ranges at which the processes of germination, growth and spore production are not affected. INCAM 11 was selected for application in the plantain and banana germplasm bank of INIVIT due to its behavior in the type of soil of that scenario, with a particularly acidic pH.
- *Dosage and time of application*: In the methodology designed, the appropriate doses and time of application of each EBCAs have been disseminated (in the acclimatization phase of vitroplants, before and after sowing).
- *Application means:* The activities also showed how the products should be applied by mixing them with the substrates, adding them to soil or by spraying.
- *EBCAs quality and expiration date*: producers were informed that they must take this aspect into account and check the expiration date on the label, since it is proven that the shelf-life of the products applied in Cuba lasts three months.

The regulation on the sustainable use of pesticides in Cuba aims at promoting IPM and the use of biological control agents. However, it is necessary to consider the uncertainty about the benefits and costs, the effects of irreversibility and the flexibility in the adoption of this technology. It was argued that the economic evaluation of IPM using a simple cost-benefit analysis may be inadequate (Benjamin and Wesseler, 2016). These authors suggest that there is an imperative need to develop evaluation tools that take into account the aforementioned limitations, presenting the Maximum Social Incremental Tolerable Irreversible Costs (MISTIC) as a tool for such evaluation. As a result of their research, they conclude that only when the reversible incremental benefits of the IPM strategy exceeds the possible irreversible costs of said strategy by a minimum threshold (critical rate) should the introduction of biocontrol be considered.

This situation could be applied to Cuba until 4 - 5 years ago, even when the few chemical pesticides used in the country were subsidized by the state and the prices incurred by producers were much lower than the real product prices. However, as of 2019 farmers do not benefit any more of a financial support for the purchase and import of these inputs. This situation implies that the application of biological controls and, in general, of national bioproducts represents an imperative for Cuban farmers, as previously stated (D9.1).

Currently, there are weaknesses related to the training of farmers such as: i) low perception about the risk of PPN on development and productions of banana crops, ii) insufficient training of technicians and farmers in PPN management, iii) lack of comprehensive and unique guidelines for PPN management in banana and plantain, with clear instruction to technicians. Additionally, farmers were reminded about the need to carry out economic cost/benefit analyses for the application of biological inputs in the current Cuban context, where only biological inputs (EBCAs and biofertilizers) are available for crop production. Considering these weaknesses, the Cuban team will continue the dissemination work after completion of the project, in close collaboration with farmers.

Summary of technologies developed and disseminated to farmers

IPM technologies developed and disseminated	**Technology testing level**	**Communicated means related to uncertainty/effectiveness**
BW management through EPN: use of selected populations of *Heterorhabditis* sp. for weevil biocontrol, in different areas.	Farm	*Uncertainties*: effect of storage on EPN survival; efficacy of populations/strains; efficacy of selection procedure for locally-adapted EPN populations; EPN diversity range for adaptation to varying microclimatic conditions; effects of climate changes. *Measures of effectiveness*: recovery of BW parasitized specimens in inoculated farms after treatments; monitoring for evaluation of effects through the collection of prevalence and BW mortality data; increased or sustained crop yields; benefit to EPN use cost ratio = or > 1.
Tools for PPN management: agronomic and biomanagement approaches affecting nematode reproduction in the field, including biocontrol. Use of healthy planting materials from nurseries in new plantations.	Field, farm	*Uncertainties*: comprehension of significance of safe planting material use; efficacy of the quality control on propagation materials; effect of local, farm level exchange of propagation material that is at risk of being naturally infested with PPN; possible ways of spread of *Meloidogyne*, *Pratylenchus* and other nematodes in new farms/fields. *Measures of effectiveness*: replicated soil analyses in new banana farms with healthy nursery plantings to ensure low density of nematodes; monitoring farms and local areas to get PPN population dynamics data; PPN low densities thresholds (nematodes / 100 g roots: 2000 in areas well managed, with drop irrigation systems; 1500-2500 in areas not managed, with drop irrigation systems or well managed, with sprinkling irrigation systems i.e. *Fregat*®; 1000-2000 in areas lacking management), achieved through low cost, organic practices and agronomic means (i.e. soil cover, fallow and other rotations); sustainable PPN control through application of organic matter; measuring the persistance and density of biocontrol fungi, either indigenous or introduced in soil; effectiveness measured by data collected on PPN density and prevalence, in target populations. Sustained crop yields and stability of production in time; application benefit to cost ratio = or > 1.

Bioformulation of *Pochonia chlamydosporia* endophytes for inoculation in banana farms: fungus-based products and their application in banana crops, best application means and doses affecting nematodes population dynamics.	Field, farm	*Uncertainties*: availability of facilities and trained personnel for production; availability of suitable isolates adapted to a broad range of diverse climatic and soil agronomic conditions; bioformulations persistence in time; effects of local storage on the product viability; effect of target nematodes diversity (host specificity). *Measures of effectiveness*: re-isolation of the fungus from soil or roots, at regular sampling times, after initial application; prevalence of *Meloidogyne* eggs > 50%; reduction in numbers of juveniles in soil, compared to untreated plants; PPN population decline below established damaging thresholds; plant growth promotion effects observed after treatments; improved or sustained yields; application benefit to cost ratio = or > 1.
Application of *Trichoderma asperellum* bioformulations in banana farms.	Field, farm	*Uncertainties*: availability of facilities, inputs and trained personnel for production; availability of isolates adapted to diverse climatic and crop conditions; persistence and stability of bioformulations in time; effects of local storage on the product viability; effect of target pest/pathogen diversity. *Measures of effectiveness*: re-isolation of the fungus from soil or roots, at regular sampling times, after first application; reduction of Foc disease incidence or damage by > 50%; disease decline below a damaging threshold; plant growth promotion observed after treatments; improved or sustained yields; application benefit to cost ratio = or > 1.

2.2 Didactic materials produced for technicians and farmers

Two manuals were prepared, the first for work with the *National Musa Collection* and the second with Guidelines for BW and PPN management in banana/plantain in Cuba (Fig. 6, ISBN assignation is in progress). The data and information were produced by national institutes and include the results from MUSA activities, for technicians and farmers work. Is is worth to recall that the informations concering these topics are dispersed in several documents, not always available for stakeholders. The final version of the Guidelines will be presented to IPM National Board at Cuba for its official implementation at the national level, at the end of the MUSA Project.

Conferences about the following topics were prepared by MUSA team in Cuba, and used for interchanges with stakeholders or made available on the CENSA website (www.censa.edu.cu).

Figure 6. Cover of draft version of Guidelines (left) and example of power point presentation used in conferences and available at CENSA website (www.censa.edu.cu).

Short **videos** about biological products (KlamiC, SevetriC and BionemC) were prepared targeting an audience of researchers, students and farmers. Five **leaflets** were produced by CENSA in collaboration with EARTH University, for technicians and farmers. More than 100 copies of each were distributed in Cuba and digital .pdf versions were sent by email to different institutes belonging to Agriculture Ministry and farmers/technicians in different provinces (Fig. 7) .

Figure 7. Leaflets produced by CENSA for the "*F to F*" formation activities in Cuba.

3. Courses for farmers and phytosanitary technicians

Two courses were organized in La Havana (June, 2019) and Villa Clara (July, 2020). The main topics of both courses were: plant parasitic nematodes, symptoms, damage, sample collection and analysis, management tactics and use of EBCAs. A further course for PhD students was performed in March, 2020 on pests and IPM. Topics were: *Musa* spp. main pests, EBCAs and BW. The PhD program joined students from three regions, with technicians and academic personnel.

Figure 8. Course held with farmers that produce tubers and banana in Villa Clara (July, 2020).

3.1 Conferences

Conferences included phytosanitary technicians with presentation of project goals and activities, updated results and technical elements for *Musa* spp., as well as phytosanitary management (Fig. 8). Several other conferences and talks were given to farmers and technicians in national and international meetings in Cuba and during the "Biological Control Workshop" organized by partner EARTH in Costa Rica. Main goal was to increase the information background of stakeholders about the project results, IPM, EBCAs, pest management in climate change context and soil health, among other topics. These scenarios were appropriate for the interchange of experiences and dissemination leaflets generated in MUSA (Fig. 9).

Figure 9. MUSA Project presentation to sanitary technicians of Mayabeque (Sept. 2017, A) and Pinar del Rio Provinces (Dec. 2017, B). Update about results and survey with technicians in Mayabeque Province (May, 2018, C). Conferences in "One Health" Workshop at La Havana (D, E). Two days course-workshop "University-Enterprise", July 2018 in La Havana for farmers from Central America to promote the use of *Pochonia chlamydosporia*, *Trichoderma asperellum* and EPN (F, G).

Using the systematic tours made by the National Group of Tubers, banana/plantain located at INIVIT, to identify problems in crops and interchange with farmers and technicians, PhD student V. Ventura[3] developed activities with some general conferences in each municipality. Farmers and technicians received capacitation about PPN and EBCAs and other topics (Table 3).

Table 3. Conferences given by municipality, and number of attending stakeholders.

year	Municipality	Province	Number of attendants
2018	Guantanamo	Guantanamo	47
	Guama	Santiago de Cuba	36
	Rio cauto	Granma	44
	Rafael Freyre	Holguin	52
	Amancio	Las Tunas	81
	Céspedes	Camagüey	37
	Baragua	Ciego de Avila	63
	Cabaiguan	Sancti Spiritus	35
	Quemado de Güines	Villa Clara	47
	Perico	Matanzas	32
	Santa Cruz del Norte	Mayabeque	29
	Alquizar	Artemisa	61
2019	Guantanamo	San Antonio del Sur	34
	Guama	Santiago de Cuba	43
	Cauto Cristo	Granma	50
	Rafael Freyre	Holguin	42
	Quemado de Guines	Villa Clara	38
	Perico	Matanzas	48
	Santa Cruz del Norte	Mayabeque	36
	Alquizar	Artemisa	40

3.2 Work with students

Inclusion of students in theoretical and practical activities

Several students have been involved in MUSA activities to develop laboratory, semi-controlled and farm level experiments for bachelor, MSc and PhD thesis. In field experiments, the students developed relationships with farmers to learn from each others (Fig. 10). The students made presentations in different seminars, meetings and workshops organized with farmers, showing their progress, as well as at the Second International Seminar of Plant and Animal Health held in Varadero, Cuba (SISA 2019, Fig. 11). A total of three PhD, two MSc. and two bachelor degree students were involved in MUSA formation activities with farmers. The PhD students came from Mayabeque, Villa Clara and Granma Provinces, representing western, central and eastern regions, respectively.

Figure 10. Meeting of students with farmers and work in field activities.

[3] Informed consent provided.

Figure 11. Students' presentations given at the Second International Seminar of Plant and Animal Health (SISA 2019, Varadero, Cuba).

Seminars

Topics afforded were: *Pochonia chlamydosporia*, *Musa* spp. and *Melodogyne* interactions, studies on plant parasitic nematodes affecting genotypes in the *National Musa Collection* and alternatives for managemet. Attending audience included academic personnel and students belonging to the National PhD in Plant Health Program, at CENSA.

Training and conferences to students, of different levels and, from diverse universities were planned and developing. Under and post- graduate students received conferences about PPN, EBCAs and IPM. MSc. Vanier Ventura received a training at CENSA and at CNR (Italy), on PPN, mycorrhizae and molecular biology techniques. His knowledge has been used at INIVIT to improve nematology work in *Musa* spp., tuber and vegetables, offering services to farmers, and for talks in different conferences and activities (Fig. 12).

Figure 12. Conferences and lecture activities with under and post graduate students, and international training work.

Several activities were planned for 2020, in cooperation woith the UNESCO Agroecology cathedra. Howeve, they could not be developed and are still in stand by, because of the Covid 19 quarantine measurements. However, leaflets were disseminatde using WhatsApp groups (Table 4).

Table 4. Locations and number of people that received MUSA leaflets by WhatsApp groups or Email.

Region (province)	Municipality	Research center, agricultural area or University	N. of farmers (F) or technicians (T) that received formation
Artemisa	Artemisa	Sugarcane Group, area: production of banana seed.	2 T
Artemisa	Bahía Honda	Sugarcane Group, area: production of banana seed.	1 T
Artemisa	San Cristobal	Sugarcane Group, area: production of banana seed.	1 T
Artemisa and Havana		Sugarcane Research Center (INICA), producing food (including banana/plantain) for own workers.	12 (researches and technicians)
Artemisa	Bauta	Grains Research Institute (IIG), producing food (including banana/plantain) for own workers.	15 (researches and technicians)
Mayabeque	Several municipalities	Agronomy Faculty (UNAH).	31 students
Mayabeque	Several municipalities	Agronomy Faculty (UNAH).	25 F

4. Summary of formation and dissemination activities

The formation and dissemination activities carried out during MUSA work are summarized in Table 5.

Table 5. Summary of main activities developed in MUSA to enhance knowledge of Cuban technicians and farmers as part of "*F to F*" activities.

N.	Activities / topic of presentation	Speaker	Location	date	N. of people involved
	2017				
1	Conference: Presentation of MUSA Project to Plant Health authorities	B. Peteira	Pinar del Río	November	7
2	Conference: Presentation of MUSA Project to Plant Health authorities	B. Peteira	Mayabeque	November	33
3	Conferences about diagnostic and pest management with emphasis on Plant parasitic nematodes	M. G. Rodríguez	University of Pinar del Río	November	27
4	Conference: Presentation of MUSA Project to	B. Peteira	Pinar del Río	November	27
	2018				
5	Conference: Use of molecular techniques for develops biological control agents in Cuba.	B. Peteira	Int. Congress, *Control Biológico de Plagas y Enfermedades para una Agricultura Sostenible*, Costa Rica	September	
6	Conference: Development and use of entomopathogenic nematodes in Cuba	M. G. Rodríguez			
7	Conference: The capacity building: role and activities related to the Biological control adoption.	M. A. Hernández			
8	National Conference "One Health": Plant-pathogens interactions	B. Peteira	Havana	October	35
9	National Conference "One Health": Essentials oils and plant product for plant health	O. Pino			
10	National Conference "One Health": Soil Health and nematodes	M. G. Rodríguez			
11	Conference: Update of MUSA Project to Plant Health authorities	B. Peteira	Mayabeque	May	10~15
12	Course-workshop "*From Academy to enterprise*: Pest management in climate change context"	M. G. Rodríguez	Havana	July	> 40 farmers from Central America
13	Course-workshop "*From Academy to enterprise*": EPN	M. G. Rodríguez			
14	Course-workshop "*From Academy to enterprise*". Aceites esenciales con efecto insecticida	O. Pino			

15	Course-workshop "*From Academy to enterprise*". SevetriC - Trichomax: *Trichoderma asperellum*, cepa *Ta.* 13	B. Martínez			
16	Work with farmers at INIVIT and Nueva Paz fields experiments				
	2019				
17	Entomopathogenic nematodes in Cuba: from laboratories to agricultural pest management (oral presentation)	M. G. Rodríguez			
18	*In vitro* effect of the entomopathogen nematode H*eterorhabditis amazonensis* hc1 strain on adults of *Cosmopolites sordidus* (Germar)	D. García	Varadero, Cuba: International Seminar on Plant and Animal Health (SISA, May 2019)		
19	Effect of selected abiotic factors on *Heterorhabditis amazonensis* Andalo *et al*. strain Hc1 viability, movility, and infectivity (Poster)	G. Calabuche			
20	New isolates of *Pochonia* spp. with potential as endophyte biological control agents on plantain and banana (*Musa* spp.) crops (Poster)	D. Maykel Sariol			
21	Development of *Pochonia chlamydosporia* and *Trichoderma Asperellum* as microbial control agents for pests in Cuba	J. Arévalo			
22	The function of training in the adoption of biological control. Study of the KlamiC® case	M. A. Hernández			
23	Compatibility of KlamiC® with agrochemicals used in the acclimatization phase of vitroplants of plantain cultivar 'CEMSA ¾'	R. Alfonso de la Cruz			
24	Diplomate Course for Plant Heath technicians of Havana (Topics about plant parasitic nematodes)	M. G. Rodríguez	Havana	June	15
25	Work with farmers at INIVIT and Nueva Paz fields experiments		Nueva Paz		
	2020				
26	Seminar at National PhD Program: New studies about *Pochonia*/banana	D. Maykel			
27	Seminar at National PhD Program: *Meloidogyne*-banana interaction	S. Gorita			
28	Seminar at National PhD Program: Plant parasitic nematodes affect National *Musa* collection	V. Ventura	Mayabeque	January	15

29	Conferences in MSc. Course (Agrarian University of Havana) about plant-pathogens interactions and induced resistance	B. Peteira	Mayabeque	January	5
30	Seminar of Provincial Young Research at Mayabeque: selection of BW traps	D. García	Mayabeque	February	60
31	Seminar of Provincial Young Research at Mayabeque: olfactometer modification to use in entomopathogenic nematode studies	G. Calabuche	Mayabeque	February	60
32	Conferences in PhD Course about plant pests: topics about plant parasitic nematodes and IPM	M. G. Rodríguez	Mayabeque	March	15
33	Conferences in MSc. Course (Agrarian University of Havana) about Plant Pests: topics about plant parasitic nematodes and IPM	M. G. Rodríguez	Mayabeque	March	3
34	Conference about botanic products for pest management in National Workshop of Essential Oils and its use in human, animal and plant health	O. Pino	Havana	March	50
35	Conference: Course for farmers that produce tuber and banana / plantain in central region of Cuba: Presentation about plant parasitic nematode on *Musa* spp.	V. Ventura	Villa Clara	July	20
36	Work with farmers at INIVIT and Nueva Paz fields experiments		Nueva Paz		

5. References

Benjamin, E. O, Wesseler, J. H. H. (2016). A socioeconomic analysis of biocontrol in integrated pest management: a review of the effects of uncertainty, irreversibility and flexibility. *Wag. J. Life Sc.* 77, 53–60

Cárdenas, A. (2003). Metodología para la promoción de la Agricultura Ecológica. Actividades y Herramientas. Movimiento Agroecológico "De campesino a campesino". Asociación Nacional de Agricultores Pequeños (ANAP), La Habana, Cuba: 63 pp.

Díaz T. (2015). La capacitación, una necesidad para el desarrollo de los sistemas productivos. 1ra Ed. Editorial Agroecológica, La Habana, Cuba: 24 pp. ISBN: 979-959-7210-87-0.