PROJECT FINAL REPORT

Final Publishable Summary Report

Grant Agreement number: 314241

Project acronym: BIOMUSH

Project title: Early detection and bio-control of mushroom pests and diseases in an Integrated Pest Management approach to comply with the European Directive 2009/128/EU"

Funding Scheme: FP7-SME-2012-2

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Final report: 1st ☐ 2nd X☐ 3rd ☐ 4th ☐

Period covered: from 01/11/2012 to 31/10/2015

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm; logo of the 7th

Declaration by the scientific representative of the project coordinator[1]

I, as scientific representative of the coordinator1 of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

  ☐ has fully achieved its objectives and technical goals for the period;

  ☒ has achieved most of its objectives and technical goals for the period with relatively minor deviations[3];

  • has failed to achieve critical objectives and/or is not at all on schedule[4].

- The public website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Ms. Margarita Pérez

Date: 22/12/2015

Signature of scientific representative of the Coordinator:

FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

3 If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

4 If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

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1. Executive Summary

The cultivation in Europe of the edible mushrooms Agaricus Bisporus is an economically valuable industry that employs 55,000 people with a yearly production of 1,200,000 tons and 1,500M euros yearly sales. Pests and diseases in this industry cause a loss of 65M euros every year related to pest control. The main pest insects causing crop losses in Europe are Sciarid flies, whereas the main diseases are the fungus Verticilium, Mycogene, Dactylium and Trichoderma.

Many chemicals are no longer approved for use in mushroom cultivation, with an increasing demand for a reduced pesticide use. Mushroom growers are under an increasing pressure to implement alternative solutions on the basis of Regulation (EC) No 1107/2009 and Directive 2009/128/EC. The mushroom growers need quick actions and IPM solutions in order to adapt to a stringent legislation to reduce pesticide use.

BIOMUSH project aims to help European mushroom growers to implement IPM as part of their growing activities, both to comply with the upcoming legislation and to reduce crop losses and production costs by efficiently managing pests and diseases.

BIOMUSH promotes an integrated approach for pest and diseases control in mushroom cultivation in order to help the growers to adapt to a stringent EC legislation aiming at reducing the pesticide use. This approach consists on:

1. Early detection tool for mushroom fungal diseases in situ, to facilitate the control of competitor fungi and fungal diseases before visual symptoms appear by means of tracking extracellular biomarkers in an advanced bio sensing system, able to detect 6-10 days earlier than visual symptoms (enough time to treat).

2. BIO Treatment of pests and diseases by bio insecticides based on natural enemies and bio fungicides based on vegetable extracts, able to control of fungal diseases (80% for biofungicides, 70-60% for bioinsecticides) with a maximum reduction on Agaricus mycelium of 5%.

3. Crop specific guidelines for Integrated Pest Management in mushroom crops in Europe, covering the mushroom pests and diseases and their detection with the help of the biosensor, bio fungicides and bio insecticides.

4. Training to professional users and distributors, with a focus on the existing IPM principles and current solutions, prevention measures and on the use of the Biomush innovation.

The impact of the BIOMUSH integrated solution will be high in the EU considering that facilitating the implementation of IPM techniques in mushroom, growers will be able to comply with the upcoming legislation, which aims to reduce the pesticides use per farm by at least 70% (3,472 Tons in Europe after 5 years) by encouraging natural pest control mechanisms. The combined approach of early detection of fungal diseases and use of bio pesticides will provide a tool that will allow for a reduction of yield losses caused by pests and diseases by around 48% keeping the current profit margins.

2. Summary description of project context and objectives

The white button mushroom (Agaricus bisporus) leads mushroom crop worldwide, in such a way that 1,200,000 tons of these mushrooms produced in Europe, 60% was sold fresh and the remainder was canned. This cultivation is an economically valuable industry with a yearly production of and 1,500M euros yearly sales. Pests and diseases in this industry cause a loss of 65M euros every year related to pest control. The main pest insects causing crop losses in Europe are sciarid flies, whereas the main diseases are the fungus Verticilium, Mycogene, Dactylium and Trichoderma.

EU SME mushroom growers are struggling to maintain benefit margins due to the globalization of agricultural markets, competition with countries like China (45% of world production), the increasing cost of raw materials/utilities and losses caused by pests and diseases. For the control of those losses chemical pesticides and fungicides are the most common used solution.

From 21st October 2009 the Directive 2009/128/EC of the European Parliament and of the Council has established a framework for community action to reduce pesticide use to a minimum and to minimize its negative impact on the environment and human health. This regulation makes implementation of the principles of Integrated Pest Management (IPM) obligatory:

- Measures for prevention and/or suppression of harmful organisms
- Tools for monitoring
- Threshold values as basis for decision making
- Non-chemical methods to be preferred
- Target-specificity and minimization of side effects
- Reduction of use to necessary levels
- Application of anti-resistance strategies
- Records, monitoring, documentation and check of success

The ban of traditional pesticides by the Directive 2009/128/EC makes necessary to develop treatment and prevention alternatives to keep the benefits/margins that makes the mushroom growing activity economically sustainable.

The overall objective of BioMush is to provide practical solution to help the growers to adapt to a stringent legislation above mentioned aiming at reducing the pesticide use at the same time it reduces losses by pest and diseases, increasing production. BioMush is an IPM solution to manage diseases spread and pest population using several control options mainly biological, physical and other non-chemical methods.

BioMush promotes an integrated approach for pest and diseases control in mushroom cultivation that works on four areas:

- Early detection tool for mushroom fungal diseases, to facilitate their control before visual symptoms appear.
- Treatment of pests and diseases by biopesticides, mainly bioinsecticides based on natural enemies and bio fungicides based on vegetable extracts.
- Crop specific guidelines for Integrated Pest Management in mushroom crops in Europe, including the developed tools.
- Training to professional users and distributors on the existing IPM principles.

The Biomush partnership has been ideally placed to develop and exploit this technology. The consortium consists of 11 carefully selected organizations from 7 European countries that together represent the most significant mushroom associations across Europe: ANICC (France), GEPC (European), AIF (Italy), SBGU (Poland), ASSOCAMPI (Spain). It also has carefully selected supply chain SMEs for both the production of the sensors technology (EST from UK and LINCIS from PT) and biological products (Agron from Israel), and RTO centres with expertise for the development of the different BioMush expected technology: INSP (SP) for sensing system, CTICH (SP) in development of biofungicides and CTC (FR) in bioinsecticides.

BioMush project looks for some scientific, technological and integrated objectives:

Scientific objectives:

1. To find and track biomarkers of fungal pathogens causing the main mushroom diseases.
2. Selection of the Vegetable extracts from commercial products with no negative effect on Agaricus bisporus growth.
3. Selection of the Biological agent for flies control mainly based on natural enemies.

Technological objectives:

1. A device able to early detect the selected biomarkers that cause fungal pathogens.
2. Development of a bioinsecticide solution for the control of pests (sciarids and phorids) in mushroom crops.
3. Development of a biofungicide for the control of fungal diseases (Verticillium, Dactylium, Mycogone). Formulation, application timing and rates.

Integrated objective:

Practical IPM guideline for mushroom crops and Training program

3. Description of main S & T results/foregrounds

The actual developments obtained for each result after the execution of the BIOMUSH project have been:

1. The biomarkers profile for mushrooms disease (Verticilium, Mycogene, Dactylium) has been established from the fixed time window after casing. Trichoderma Viride was decided to be excluded from the group of diseases due to it is usually coming with the compost and there is another EC project directly devoted to control it, namely MushTV. In this way, the EC resources assigned to BioMush are better managed and concentrated in the three mentioned diseases.

2. The Sensing system is based on an array of sensors developed ad-hoc for the project that give a response in the presence of the defined biomarkers. Reproducibility and sensitivity of the sensors were checked with good results.

3. In parallel, the electronic subsystem has been fabricated to measure and interpret the readings. It included the interface with the sensors, the sensor conditioning electronics, the microcontroller running software, the control and decision software and the user interface of the application. All these parts have been embedded into a handheld device.

4. Vegetable extracts have been selected from those commercially available, screened by efficiency against the different diseases using in vitro (Petri plate) and in vivo tests (compost blocks) with induced infestation.

5. Selected fungicides and fungicides doses have been used to field trials. Experiments were designed in order to guarantee real and reproducible results, applicable to commercial cultures. To evaluate the biofungicides efficiency two parameters were controlled: Average yield and Biofungicide effectiveness, using the most common chemical products as control. In many of the cases, the obtained yield with the fungicide treatment is higher than that obtained with chemical treatment and similar effectiveness results are obtained with the BIO to those obtained with the chemicals (80%).

6. Selected Bioinsecticide was initially evaluated using natural enemies. Flies are continuously breaded and supplied to cultivation blocks under study at different period of the cultivation cycle. The main parameters evaluated have been Average yield, effectiveness and average number flies by trap. The results showed good yield (70-60%) with the selected bioinsecticide than without treatment, but in any case better that the current chemicals.

7. The developed sensing system has been tested in large-scale experimental growing rooms with induced infestation. Tests have been directed to a final validation of the entire electronic device and the data collected to optimize the developed SW with a correction of parameterization. The device has been able to early detection of the diseases (6-10 days earlier than visual symptoms appears), what gives growers enough time to treat.

8. In the same test, large-scale experimental growing rooms with induced infestation, the efficiency of the biofungicides applied either after the sensor detection of the disease, or as preventive treatment before induced infection in combination with the sensing device has been evaluated with good results. These test have narrowed the range of the biofungicides to be tested next based on the most efficient.

9. The entire solution (the sensing device, biofungicides, and bioinsecticide) have been validated in different commercial farms without induced infection. Good compatibility of the different innovations have been found with low interference. The impact of the treatments in the productivity has been checked and can be considered negligible. Some formulations even showed an increment compared with the blank with no treatment. The efficiency of the sensing device has been confirmed being again able to early detect the infection before visual symptoms appears.

10. A guideline for Mushroom growers including the use of the innovations developed during the project have been produced, with the aim to allow managing a crop that need to deal with possible contaminations from pests and diseases. It will consider the different culture techniques and possible infection periods. The main aspects that this guidelines have covered are:
    - Preparation to the crop focusing on aspects such as premises characteristics, disinfection and hygiene in general.
    - Mushroom pests and diseases and its detection: early detection with BioMush sensor, visual, or confirmation tests through laboratory analytical methods.
    - Management of these pests and diseases both preventing and treating after detection.

4 Potential impact and main dissemination activities and exploitation results.

POTENTIAL IMPACT ON EU SOCIETY

There are a number of benefits to the EU that will be provided by the BioMush project and these include

1. Increase competitiveness of European Mushroom growers

BioMush will increase European mushroom production by at least 4.8% as a consequence of a reduction by 75% of the yield losses caused by fungal diseases, what means more benefits for farm. So EU growers are in better position to compete with imports coming from China (45% of word production).

2. Job impact in rural areas

Mushroom cultivation has a social character since farms are normally family driven and the production also involves a series of related activities, such as spawn producers, composting plants, sellers, canning industries and compost recycling plants. Mushroom productions in Europe employs 55,000 employees mainly associated to rural areas, where the industry can favour the creation of new SMEs. The project will increase the sustainability of the rural sector and agriculture in general contributing to maintain 2400 jobs and the inclusion of women in the labour market (growers, in canning industries, etc.), meaning an injection of resources for rural areas and keeping their population.

3. Health impact for European citizens

BioMush project by encouraging natural pest control mechanisms, facilitates the implementation of IPM techniques in mushroom to comply with the upcoming legislation, and hopefully *will reduce the pesticides use per farm by at least 70%* (3,472 Tons in Europe after 5 years). In that way less harmful pesticides reach the human food chain, increasing the safety for the consumer.

POTENTIAL IMPACT ON PARTICIPANTS

SME-AGs (ANICC, SBGU, FTREV and RECOMSA) will benefit from providing tools and guidance to their SME members for an efficient implementation of an IPM program in their crops. Considering the consortium Associations represent 55% of the total growers, with BioMush project they will provide their associates with an increase in production of 65M, thus contributing to the development of the European mushroom production. Royalties will be collected from the global sales through licencing of BioMush technology, which will be reinvested for the Association's activities. Royalties for the licencing of the Biosensor and biological treatment products will be charged to non-consortium SMEs based on the demand uncovered by consortium SMEs (LINCIS, EST and AGRON).

SME acting as OTH (LINCIS, EST and AGRON). The project is going to provide SME´s opportunities to strengthen their current market position, increasing shares in their respective markets, entering new markets, and also increasing their competitiveness with added values derived from the acquired new knowledge. They will benefit from manufacturing and selling the BIOMUSH technology to the SME-AG members in Italy, France and Poland for an agreed period. SMEs LINCIS, EST and AGRON will also be able to exploit the technology in the countries where they are located.

DISSEMINATION ACTIVITIES

Relevant dissemination action where Biomush has been present are shown next:

- **Press release:** has been delivered to specialized reviews and newspapers to announce the start of the project and the beginning of the research program. Other press releases are going to be launched to specialized reviews and newspapers during the project execution to announce the main technological developments:

    - Diario de La Rioja (03/12/2012) “Hacia un champiñón riojano más ecológico”, directed to the general public (Spanish)

    - Lavanguardia.com (03/12/2012) “Asistencia del Consejero a la reunión del Projecto Biomush en el CTICH”, directed to general public (Spanish).

    - Europapress.es (03/12/2012) “Martin-asistira-manana-ctich-reunion-coordinacion-proyecto-biomush-implica-11-socios-europeos”, directed to general public (Spanish).
    - Teinteresa.es (03/12/2012) “Martin-CTICH-coordinacion-Biomush-europeos”, directed to general public (Spanish).

    - Lainformacion.com (03/12/2012) “Martin-asistira-manana-en-el-ctich-a-la-reunion-de-coordinacion-del-proyecto-Biomush”, directed to general public (Spanish).

    - La Rioja.com (31/08/2013) “Investigando-champinon-desde-Rioja”, directed to general public (Spanish).

- **Newsletters and bulletins**, have been produced as dissemination materials mainly directed to growers and involved partied in the Mushroom world:
    - Spanish Association Bulletin/Newsletter nº 70, Third quarter 2012
    - Spanish Association Bulletin/Newsletter nº 71, Fourth quarter 2012
    - Spanish Association Bulletin/Newsletter nº 72, First quarter 2013
    - Spanish Association Bulletin/Newsletter nº 74, Third quarter 2013
    - Spanish Association Bulletin/Newsletter nº 75, Fourth quarter 2013
    - Spanish Association Bulletin/Newsletter nº 76, First quarter 2014

- Spanish Association Bulletin/Newsletter nº 77, Second quarter 2014
- Spanish Association Bulletin/Newsletter nº 78, Third quarter 2014
- Spanish Association Bulletin/Newsletter nº 79, Fourth quarter 2014
- Spanish Association Bulletin/Newsletter nº 80, First quarter 2015
- Spanish Association Bulletin/Newsletter nº 81, Second quarter 2015
- Spanish Association Bulletin/Newsletter nº 83, Fourth quarter 2015
- IBET bulletin Fats & Figures Volume 2 Issue 1, March 2013. Pag 6. (English)
- La lettre du CTC (Bulletin D´Information du Centre Technique du Champignon), March 2013. In French
- Biuletyn Producenta Pieczarek (Polish mushroom industry bulletin), 4/2012, in Polish.

- **Posters:** Portuguese Congress of Microbiology and Biotechnology. December 2013. Title: Fungal Agaricus bisporus diseases, taxonomy and reality. Directed to scientific audience and other attendees.

- **Conferences:** Biomush has been present in conferences like “International Symposium on Food Safety”, hold in University of Mauritius, Julio/2015. IBET on behalf of the BioMush Consortium distributed the Bochure of the project and attend to that questions addressed by the participants about the Project. Around 125 people from EU, Brasil, China, and countries Africa attended to the Conference, mainly from the scientific area.

- **Video production**: a dissemination video presenting the project, the results, and the end-user feedback was realized by ANICC. The video was uploaded on the Website. It will be shown to the next GEPC meeting in January 2016, and it will also be shown to the growers.

- **Meetings to End-Users**
  - **Rioja Growers Association.** CTICH informed the Rioja mushroom growers at the periodic General Assembly general meeting. In these meetings are present the all growers delegates through compost yards. In these meetings CTICH informed about Biomush Projects. The meetings dates have been: 19/04/2013; 13/09/2013; 13/12/2013; 04/02/2014; 17/04/2014; 22/07/2014; 06/11/2014; 23/01/2015; 27/06/2015; 26/06/2015

  - **France Growers Association.** ANiCC and CTC informed the French mushroom growers at the general meeting that was held in France at the end of May 2014. A presentation was showed to them. The dissemination video and the guidelines will be presented to them in December 2015 at a board meeting.

- **Italian Growers Association.** FTREV has presented the presented the project at General meeting assembly that have taken place during the las year 2015.
- **Polish mushroom Association.** SGBU has presented the project to the Polish mushroom growers at general meeting, to the board members at board meetings, and at several conferences held in Poland (examples: Mushroom Conference in Wielichowo, May 18th 2013; Mushroom Festival in Siedlce, Sept. 26th 2013; Project on Mushroom Conference, Kolumna, October 1-2th 2013; Conference organized by the Polish Academy of Science, Siedlce, October 18th 2013; Conference organized by the Mushroom Produce Group,Tomaszów maz, November 14th 2013).
- **GEPC (European Mushroom Growers Group).** ANICC and CTICH have also been informing the GEPC members (the European Mushroom Growers Group which represents 9 countries in the EU) of the general purpose of the BioMush project, within the limit of confidential data, at each GEPC meeting, twice a year. In this meeting they are delegates from 9 countries in EU. Generally about 20 people. They are technical and growers association delegates). The meetings dates have been: 14/06/2013; 29/11/2013; 26/06/2014; 15/01/2015; 12/06/2015; 19/11/2015
- **Training to growers** on BioMush IPM program has been done to a group of 5 trainees chosen among SME-AGs staff with full IP knowledge of the BIOMUSH program. That trainees group are the responsible in a second stage of the massive training to members of the Biomush represented associations.

- **Especial dissemination meetings**: An intense activity has been done by the RTO performers to show technology developments to SMEs and SME-AG. Many of this activity has carried out in devoted meetings, some of them carried out after or before the consortium meeting (to save project resources), but other took place by teleconference or special visits.

- **Dissemination for influence in legislation.** Regular Communication with national authorities by participant SME-AGs (ANICC, SBGU, FTREV and RECOMSA) about the IPM progress and results to assist them to report the EC the actions taken for the implementation of directive. Once a year the national delegates in GEPC have a meeting with EU Agricultural Commission in Brussels. At this meeting, the Commission is informed of the current situation of the mushroom sector and their problems. The next meeting is held on January 16. During this meeting the results achieved during the BIOMUSH project will be commented with EC Agricultural representatives.

  At national level (Spain), there is a continuous communication between the technical people from CTICH and the technicians from the Agriculture Government of La Rioja.

- **Project web site** for the dissemination of BIOMUSH activities outside the consortium updated every 3 months. The contents have include a home page with the project presentation, a news section, project information, consortium members

and a Demo video. **Partner´s web site** is another way of dissemination of Project life and events.

EXPLOITATION OF RESULTS

BioMush project involves partners form European countries dispersed across Europe: Southern Europe (Spain, France, Portugal and Italy), Nordic Europe (UK), Eastern Countries (Poland) and associated countries (Israel). This will facilitate very good initial reach-out to European market, through first dissemination and exploitation endeavours. Involvement of 4 European regions in research (SP, FR and PT) and validation (IT) activities under BioMush will pave the way for more widespread uptake of delivered technology, allowing for achieving European-scale impact.

The Biomush project Foreground exploitation strategy is constructed under following pillars:

- To identify key user groups who have influence in their own regions.
- To work with end users groups to test and trial product ensure the end product is what the market needs
- To develop product Champions throughout Key European markets.

Consortium has done a market search identifying: market needs, target customers, market segment, competitors. A strategic approach for investments and commercial activity and an implementation schedule has been developed. The business plan has estimated pricing for the final results and a sales forecast.

BioMush solution (combination of sensing system, biofungicide and biounsecticide) is directed primarily at mushroom growers across Europe but also to member states to facilitate taking actions for the implementation of directive 2009/128/EC. It is crucial for the continuation of their bussines count with new tools to fight against diseases and pest after applying the legislation.

As secondary market, we can consider other potential fields where BioMush could have a direct or indirect application apart from mushrooms farms. These can be biopesticides market for other agriculture cultivations such as salad vegetables, soft fruits, orchard fruits, vineyards, row crop such as corn and vegetables, cotton and tobacco. Another one could be the field of sensors for metabolites detection in agro-food area such as casing soil companies, agro-product suppliers and R&D entities.

After the project has ended, the main project innovations beyond the state of the art and their patentability have been revised. Those results identified as freely patented have been communicated to the owners to take the decision about their protection. Preliminary decision of protection of the results has been taken by the SME-AG according to their interest and the nature of the result. Sensing device and Biofungide formulation can be patented. Bioinsecticide and Guidelines cannot be patented but access will be granted to growers by different means.

ANICC, as Exploitation Manager, is in charge of applying for the resultant patents and will deal with the IPR adviser and filing agent for the correct patent application, and also deal with possible conflicts in the application.

The BioMush Consortium has agreed a product production strategy taking into account that partner manufacturing capabilities will satisfy the needs of the supply chain. SME-AG owns the results and licencing participating SME for manufacturing of the results in non-exclusive basis for an agreed period of time. The market demand not covered by the participating SMEs will be do it by other SMEs that will compensate the SME-AG with a percentage of the sales as royalties, in such amount that not compromise the market price of the final products.

Regarding market penetration, National Associations participating in the project cover 55% of the total production in Europe. Since a transition period is expected from growers to implement the guidance and technology, our approach is to achieve that 55% penetration over the period of 3 years, starting with a penetration of 35%, increasing gradually to reach that 55%. Mushroom associations members of the GEPC cover 96% of mushroom growers in Europe. The technical Committee of the European association GEPC, based in ANICC offices, together with the legislative pressure to implement the directive to reduce pesticides use and with the aid of associations external to the consortium, can achieve 70% of penetration in European mushroom farms over a 5 years.

5. Address of project public website and relevant contact details

5.1. Consortium Members

PARTNER	SHORT NAME	COUNTRY
Asociacion Profesional de Cultivadores de Champinon de la Rioja,Navarra y Aragon	CTICH	Spain
Association Nationale Interprofessionnelle du Champignon de Couche	ANICC	France
Stowarzyszenie Branzy Grzybow Uprawnych	SBGU	Poland
Consorzio Funghi di Treviso Societa Cooperativa Agricola	FTREV	Italy
Reciclados de Compost de la Mancha scl	RECOMSA	Spain
Electrochemical Sensor Technology (est) limited	EST	United Kingdom
Lincis Solucoes Integradas para Sistemas de Informacao Lda	LINCIS	Portugal
Agron Agrochemicals Development and Marketing ltd	AGRON	Israel
CTC Centre Technique du Champignon	CTC	France
Tecnologias Avanzadas Inspiralia sl	INSP	Spain
Instituto de Biologia Experimental e Tecnologica	IBET	Portugal

5.2. Project Contact and Logo

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