PROJECT FINAL REPORT

Final Publishable Summary Report

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Project acronym: GREENAVOID

Project title: ***Greenhouse solution to avoid film cover U.V. and sulphur degradation***

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Date of latest version of Annex I against which the assessment will be made:

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

Period covered: **from** **01/12/20112** **to** **30/11/2014**

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

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: Mr. Gerard Marquès Tura

Date: 30/01/2015

Signature of scientific representative of the Coordinator:

[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

In Europe, cultivation in plastic greenhouses has permitted the conversion of apparently unproductive farmland into modern agriculture holdings. Different types of plastics, such as polyvinyl chloride (PVC), polycarbonate (PC) and low density polyethylene (LDPE), are commonly used for covering greenhouse structures.

However, most of the plastic polymer films are prone to photo degradation when exposed to UV radiation (290-400 nm) or even visible radiation (400-700 nm). In warm regions, the combination of UV radiation with agro-chemical agents used in the greenhouses aggravates the problem of plastic cover degradation substantially. Durability is one of the aspects that most interest and concern end users. Therefore, the manufacture of plastics resistant to treatments performed in greenhouses is one of the current battlefields, where products such as sulphur and, chlorine which are used to control pests, have become the greatest enemies of the farmer. Sulphur is especially aggressive and the current method of application has a great impact on the degradation of films used as cover in the aforementioned greenhouses.

GREENAVOID project aims to develop an innovative system which offers to farmers an integrated solution to its problem by combining a new polyethylene greenhouse plastic resistant to UV degradation in the presence of burning Sulphur without harmful films stabilizers, together with an improved Sulphur vaporizer designed to minimize the amount of product reaching the plastic cover.

GREENAVOID concept consists in developing of a multi-layer film each one with different properties: the outer layer will contain an inorganic UVA (Ultra Violet Absorber) additive (avoiding the use of organics UVA's and quenchers) and the inner layer will contain a inorganic additive specifically modified for protection against sulphur exposure, providing also the required resistance to the high temperature contact point with the greenhouse structure. Complementing the development of this innovative film, a new sulphur sublimator less aggressive with the film has been designed, providing a better and homogeneously application of sulphur on the plant with good crop area coverage at the same time reduces SO_2 emissions.

GREENAVOID solution is oriented to achieve an agricultural film with 3 years warranty in the presence of sulphur up to 3500ppm in plastic and under light radiation of 145-150 K Langley's/year (average radiation in southern Europe). In addition, it offers a minimum of 85% PAR transmittance and UV blocking.

The impact of the GREENAVOID integrated solution will be high in the EU considering, not only the total revenue generated in SMEs, but also improvements in grower's competitiveness by savings in plastic replacement, savings in energy for polyethylene production and also Increased competitiveness in the European Masterbach sector reducing imports from China and India. The reduction in release of carcinogenic products like Ni-quenchers and dioxin emissions to the environment in the plastic recycling could be an important benefit in human health.

2. Summary description of project context and objectives

Greenhouse cultivation under plastic has allowed converting apparently unproductive lands into modern agriculture exploitations. Worldwide there were 800,000 hectares covered by film greenhouses in 2009. Europe covers at present 20% of the global film greenhouse area, contributing specially to the agricultural income in many less favoured regions of southern EU countries. The Mediterranean region of Europe has one of the largest concentrations of protected crop production in the world being Spain the country with a bigger cultivated area, followed by Italy, Turkey and Morocco.

European farmers are facing difficulties in the present economical context with an increase in production costs together with a decrease in selling prices, forcing farmers to survive in an industrial sector where the profit decreases every year, with reduction of governmental funds and elimination of protectionist trade barriers. Turkey and Morocco are showing a rapid growth in greenhouse agriculture; they have cheaper labor cost and are an important threat for the European market. In this scenario European farmers cannot stand amortization costs and, as a consequence, many are forced to cease activity.

Current greenhouse films, in order to avoid plastic degradation, include in its formulation harmful films stabilizers such as Ni-Quenchers, which are classified as class I carcinogenic, and Ultra Violet (UV) Absorbers, which alter the hormonal balance of the organism. Moreover, Dioxins, highly toxic products released in the uncontrolled incineration of plastics, are also released from the plastic due to the accumulation of chlorine pesticides in the greenhouse cover film.

GREENAVOID project aims to develop an innovative system which offers to farmers an integrated solution to its problem by combining a new polyethylene greenhouse plastic resistant to UV degradation in the presence of burning Sulphur without harmful films stabilizers, together with an improved Sulphur vaporizer designed to minimize the amount of product reaching the plastic cover.

GREENAVOID concept is a new innovative system which offers to farmers an integrated solution for its problem. It consists in developing two products:

- A multi-layered film with two different properties: the outer layer contains an inorganic UVA (Ultra Violet Absorber) additive (avoiding the use of organics UVA's and quenchers) and the inner layer contains a inorganic additive for protection against sulphur and chlorine gas exposure, providing also the required resistance to the high temperature built up in the contact point with the greenhouse structure.

- A new sulphur sublimator less aggressive with the, providing a better and homogeneously application of sulphur on the plant with good crop area coverage at the same time reduces SO_2 emissions.

The Greenavoid partnership is ideally placed to develop and exploit this technology: CCP Masterbatch (Spain) has expertise in Masterbatch production, Marion Technologies (France) in nanomaterials and Soli (Israel) in greenhouse industry. Other two SME selected as final users are Apofruit having expertise in farmers and Solplast which is one of the most important polyethylene greenhouse film blowers. We have also identified 3 RTD partners to help us to develop Greenavoid solution: Fraunhofer (Germany) with specific expertise in the fields of plastic and elastomer technology, CETEC (Spain) specialised in plastic tests and with previous projects in agriculture and Inspiralia (Spain) specialised in electronic systems development and computer simulation.

GREENAVOID project aims several scientific and technological objectives.

Scientific objectives:

1. To study the degradation and durability behaviour of different PE inorganic nanocomposites under different environmental conditions.

2. To study the effect of different inorganic materials and different encapsulation techniques to obtain a maximum transparency in the PAR spectrum while keeping the UV reflection.

3. To study the effect of different microencapsulation and particle modification techniques on the dispersion of inorganic particles to prevent agglomeration.

4. To increase knowledge in the distribution of sulphur in the greenhouse under different conditions.

Technological objectives:

1. To modify the structure of an inorganic nanoparticle to obtain a maximum dispersion in the reaction batch and PAR transparency in the polymer.

2. To develop a PE-inorganic nanocomposite stable in biotic environments resisting to UV light degradation under oxygen atmosphere.

3. To compound the nanoparticles into polyethylene melt to produce a Masterbatch.

4. To develop an agricultural film integrating the developed Masterbatch.

5. To develop an integrated solution of a film cover resistant to sulphur treatments in greenhouses.

6. To develop of an improved sulphur vaporizer.

3. Description of main S & T results/foregrounds

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

1. Selection of the best inorganic materials and different encapsulation techniques to obtain nanomaterials with a maximum transparency in the PAR spectrum while keeping the UV reflection.

2. Selection of the best inorganic materials and different modification techniques to obtain nanomaterials for protection against sulphur vapour exposure, providing also the required resistance to the high temperature that used to be in the contact point with the greenhouse structure. One layer films containing each one a different type nano-material has been blown and characterized for thermal nanoparticles dispersion by X ray diffraction (XRD) and transmission electron microscopy (TEM), oxygen and sulphur permeability, optical properties and mechanical properties, UV stability with weathering test (with and without sulphur exposure).

3. Selection of the formulation of the PE Masterbatches containing both types of the nanomaterials above mentioned attending not only to transparency criteria but and easy manufacturing process. In that sense, monolayer films from each combination were blown and checked by analytical methods to confirm that they have not loosen properties that affect to transparency or barrier effect during their pass through the extruder.

4. Production of several kilograms of Masterbatches from both types of nanomaterials according to the best test defined in paragraph 3 to be sent to the industrial manufacturer.

5. Production of around 400 kg of multilayer film in an industrial blower using the Masterbatchaes of nanomaterials prepared before, and study the mechanical, thermal and light properties with and without UV light and sulphur exposure ready to confirm not losing properties. Film was ready to be used in the field test.

6. Patterns of sulphur accumulation in films in real cultivation campaigns have been determined by on-field sampling and further laboratory analyzing.

7. Pattern of air movement in real cultivation greenhouses, which has been incorporated to a Computational Flow Dynamics model. It has considered not only the physical elements and dimensions of the greenhouse but the presence the crop itself.

8. Using both patterns mentioned in the above paragraphs, it has been built a mathematical model of sulphur vapour movement and distribution in the whole cultivation greenhouse, which has been validated with high reliability by comparison with real field data took on sublimation campaign in pepper crops (Murcia, Spain).

9. Design of a new concept of vaporizer that reduces the sulphur vapor that is sent to the plastic roof. The design of a new vaporizer started with the analyzing of the state of the art, revealing that commercial vaporizers present low complexity, low price and high fields for improvement. These improvements were designed using the model of sulphur distribution built before in such a way that different sublimation scenario can be compared and decide about the benefits of each element (without the need of testing).

10. A pre-production prototype of Greenavoid vaporizer has been built following the design produced in the previous task. Firstly, physical elements were selected and procured fitting the requirements of the design and the project constrictions (simplicity, robustness and price). Then, they were assembled in the different units following the design and later on all were integrated in a lab prototype. Specific software was developed to take control of the electronic of the vaporizer via PC, very useful for the test (lab and on-field).

11. Integration of both product of the project, plastic film and vaporizer were done in the field test for 5 months. They were compared with the current solution combining the elements in 4 experimental greenhouses of 100 m^2 of projected area each: experimental film + experimental vaporizer, experimental film + commercial vaporizer, commercial film + experimental vaporizer, commercial film + commercial vaporizer.

12. Positive Validation of the field test results of both products by SME comparing the project developments with the current solutions, in both aspects technical and economical.

13. Finally, Greenavoid integrated solution has consisted of:

A. A three layer plastic film of longer life durability based on selecting the stabilizers, the base polymer and the extrusion system, and composed of:

- An upper layer with UV protection effect.
- An inner layer with barrier properties and thermal properties
- A middle layer to reinforce and improve agronomic properties.

With the following functionalities:

- 3 year guaranteed resistant to sulphur under light radiation of 145-150 K Langley's/year (average radiation in southern Europe).
- Able to resist at concentrations of 3500 ppm sulphur in plastic
- Minimal absorbance in the UV spectrum while keeping a transparency of the PAR radiation of at least 85%, 30-35% haze.

B. A sulphur vaporizer system less aggressive on that film, with the following functionalities:

- Homogeneously application of sulphur on the plant with good crop area coverage.

- Including a protective devices system that will avoid direct spread of the sulphur on the plastic film
- Obtaining a reduction of sulphur accumulation in the plastic

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 Greenavoid project and these include:

1. Displacement of non-EU products.

   One of the additional benefits to the EU is that the sales in Europe and also the rest of the World will be at the expense of other suppliers of competing systems which currently are from outside Europe (mainly India and China). Ni-Quenchers are at present commonly used in masterbatches in combination with other stabilizers to provide plastics with chemical resistance since they are relatively inert to attack from sulphur. European Masterbatch producers are dependent on the Ni Quencher technology, solely produced in China, to provide resistance to sulphur in the film. Development of Greenavoid product will break that dependence on a carcinogenic product like the Ni-Quenchers by developing a new technology to produce a masterbatch that substitutes Ni quenchers by other stabilizers to provide resistance to agrochemical degradation to the film. This project will increase the competitiveness of the EU in this market.

2. Reduced the plastic waste.

   As a result to high speed deterioration of agricultural films, uncontrolled greenhouses in some places like south Europe account for a 30% of the total waste generated, and which uncontrollably burn and abandon. The total volume of waste generated by the agriculture is difficult to quantify. Plastic recycling implies an added cost for farmers and therefore there is still a big amount of illegal burning and dumping of waste plastics on-farm.

3. Health impact for European citizens

   GREENAVOID will lead to the reduction of agricultural plastic film wastes developing films with a longer life and will avoid the presence of these harmful stabilizers in the film. Uncontrollably burn can generate big amount of hazardous contaminants including dioxins.

4. Energy and resources savings.

   Replacement of a one year agricultural film by a three year one means reducing the tonnes /year of plastic that need to be produced and in a direct way the LDPE and the energy in during their manufacturing. This will clearly save resources from oil.

POTENTIAL IMPACT ON PARCIPANTS

The project is going to provide SME´s opportunities to strengthen their current market position, increasing shares in their respective markets, and entering new markets, also increasing their competitiveness with added values derived from the acquired new knowledge by overcoming the following challenges:

- Liberating from the current pressure on competition from low cost labour countries.

  Changes in the structure of the film industry in recent years threaten the survival of European small enterprises in film related products in the masterbatch industry. We are facing the competition of countries like China, in which the Masterbatch market is one of the fastest growing (8%/year) in the world. Developing an innovative Masterbatch for our product application CCP will increase our competitiveness with important expected revenues of after year 5. The innovative masterbatch will displace imports of masterbatches from China, especially those including Ni- Quenchers in their formulation by offering the same functionalities without all the drawbacks of the Ni-Quenchers already mentioned.

- Radically improving the market situation of end users.

  European farmers are facing difficulties in the present economical context with an increase in production costs together with a decrease in selling prices, forcing farmers to survive in an industrial sector where the profit decreases every year, with reduction of governmental funds and elimination of protectionist trade barriers. Turkey and Morocco are showing a rapid growth in greenhouse agriculture; they have cheaper labour cost and are an important threat for the European market. In this scenario European farmers cannot stand amortization costs and, as a consequence, many are forced to cease activity. The proposed solution will have a positive impact on European growers by reducing the cost of the replacement of the plastic cover increasing their competitiveness. GREENAVOID offers a technological development that will increase grower´s competitiveness, in costs of replacing the greenhouse film and reallocating the labour used in the process of installing, withdrawal and whitewashing to other critical functions like harvesting, crop removal and sowing.

- Meeting and understanding the demands of todays' end users.

  The project has provided a cost efficient system that will allow the end user important savings /Ha by offering a Plastic cover with a guaranteed durability of 3 years in the presence of burning sulphur. Cooperation with the RTD performers has helped SME´s gain valuable knowledge with respect of the Mastebatch and polymer engineering. With this knowledge and meeting the end user´s demand, SMEs can also gain access to other markets like Chile, with high UV radiation, where producers complain that plastics last only for 2 to 3 growing seasons.

DISSEMINATION ACTIVITIES

Several partners have attended to different dissemination events where the prepared communication materials (e.g. project brochure, PPT´s) have been distributed. Relevant events where Greenavoid has been present:

- Conference: 7th International Agricultural Film Conference organized by Applied Market Information Ltd that took place from the 15-17 September 2014 at the Crowne Plaza Barcelona Fira Center in Barcelona, Spain. CETEC attended this conference on behalf of Greenavoid Consortium that count with enterprises worldwide from the plasticulture industry, some of which are clients of CETEC. An on-line interview with SOLPLAST and CETEC was published in Interempresas.net.

- Trade fair: 13th Week of Science that took place from the 7-9th November 2014 in the city of Murcia-Spain. CETEC on behalf of the Consortium participated in the table top exhibition together with 34 institutions like Universities, research institutes, innovation centres, enterprises, outreach associations and government agencies. CETEC set its own stand where they showed to the public their R & D activities and projects, including their projects in the 7th Framework European, such as Greenavoid.

- Scientific article: Inspiralia has presented a scientific paper to be published in the Journal “Biosystems Engineering”, with the title: “Study and analysis of sulphur vapour distribution produced during sublimations occurred in closed greenhouses through numerical simulation methods”.

- Poster with information about the project was produced as support of the leaflets with the aim to capture the attention of the attendant to the fair or event where the poster has been posted

- Dissemination at end-users. The consortium has kept in contact with national associations for agriculture and plastic, like CEPLA (Spanish committee of plastics for Agriculture) in order to support industry wide take up. Contacts took place on regular basis as two of the members of the Project CETEC and SOLPLAST are also associated to CEPLA. In the last case Mr. Pedro Pablo Díez (from SOLPLAST) is also member of the CEPLA´s Board.

- Dissemination at standardization bodies. The consortium represented by SOLPLAST has made contacts on a regular basis (every six month) with the European Committee for standardization (CEN), where the project has been updated with the current and upcoming legislation and standards. At the same time, the Consortium took the advantage of SOLPLAST ´s presence in the Committee to disseminate Greenavoid project among some members.

- Pedro Pablo Díez (SOLPLAST) Interview in the Blog of Agritech Murcia. October 14th 2013. http://www.agritechmurcia.com/

http://blog.agritechmurcia.com/la-plasticultura-avanza-hacia-productos-multicapa-que-solucionen-la-degradacion-prematura-y-mejoren-sus-prestaciones/

- M. Pedro Pablo Diez interview in the magazine “Ecuador y sus flores”. October 18th 2013. Nº41

  http://issuu.com/revistaeyf/docs/revista_41_web/17?e=5567336/11048122

- Radio interview of Pedro Pablo Diez in the radio station Onda Regional de Murcia, November 2013.
- Article in the magazine Nova published by the Regional Development Agency of Murcia on March 2014. Page 22.
- Conference: “Numerical Simulation applied to sulphur vaporizer used to fight against crop diseases” presented at Workshop on Industrial Problems the University of Santiago de Compostela on the 18th October 2013

A project brochure regarding about project aims, needs to fulfil, strategy, and expected benefits to users. This brochure was translated to different languages and distributed among the partners in order to be used in every conference or trade fair they attend.

An intense activity has been done by the RDT performers to show technology developments to SMEs. 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.

EXPLOITATION OF RESULTS

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

- To identify key user groups who have influence in their own regions.
- To work with key 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 equipment and a sales forecast.

Polyethylene film covered greenhouses is the main market targeted by Greenavoid solution. This market will be accessed through the development of an integrated solution in which a more resistant plastic combined with an improved sulphur burning system will solve the current degradation problem of the films when exposed to UV, burning sulphur and chlorine, and high temperature in the contact point with the greenhouse support.

Besides the primary application in agricultural films, the developed nanomaterials also have a potential secondary market in all polyethylene applications that require

enhancement of a product's thermal stability, improve stiffness and strength, and increase gas barrier performance in outdoors conditions. The increasing demand for high-performance fillers, plastics, and composites, combined with the ability of Greenavoid developed nanocomposites with improved dispersion and stability in biotic environments will help open up many applications, including automotive (structural) and packaging (gas barrier).

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 partners according to their interest. Partners find more interesting the protection of the integrated solution for agricultural uses instead of individually protection of the results. They will remain as trade secret unless a specific application will be found, where the protection of the result could be worth.

CCP, as the coordinator of the project, 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 SME Group has agreed a product production strategy taking into account that partner manufacturing capabilities will satisfy the needs of the supply chain. Marion Technologies (M.TECH, France) will provide the nano particles, making sure their structure is compatible with the polymer. These nanoparticles will be integrated in a Masterbatch by CCP for its suitability and sulphur resistant characteristics for Agricultural films. Different masterbatch will be transformed in films and all layers will be put together in the resulting plastic by Solplast. SOLI will own and exploit the sulphur vaporizer and will have preferential commercial rights on the agricultural film. Later on Apofruit will be the end user and validate the effect of the newly developed sulphur vaporizer on the degradation of this film.

5. Address of project public website and relevant contact details

5.1. Consortium Members

PARTNER	SHORT NAME	COUNTRY
Colores y Compuestos Plasticos S.A	CCP	SPAIN
Marion Technologies S.A	M. TECH	FRANCE
Soli Industries (1981) Ltd	SOLI	ISRAEL
Centro tecnológico del Calzado de la Region de Murcia	CETEC	SPAIN
Fraunhofer- Gesellschaft zur Foerderung der Angewandten Fosrschung E.V	Fraunhofer	GERMANY
Tecnologias Avanzadas Inspiralia S.L	INSP	SPAIN
Solplast S.A.	SOLPLAST	SPAIN
Apofruit Italia Soc. Coop. Agricola	APO	ITALY

5.2. Project Contact and Logo

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Project website[5] address: www.greenavoid.eu

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