
Project no. FOOD-2005-514082

Project acronym: PROTECTOR

Project title:
Recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition

Instrument: Specific Targeted Research and Innovation Project (STREP)

Thematic Priority: 5

# Final report

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Project coordinator organisation name: Terra Humana Clean Technology Development, Engineering and Manufacturing Ltd.

Revision [FINAL]

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# *1.1. Publishable final activity report*

## Project Summary

| Project title:<br>**Recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition** | |
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| Project acronym: | **PROTECTOR** |
| EU FP6 project no. | FOOD-2005-514082 |
| Instrument: | Specific Targeted Research and Innovation Project (STREP) |
| PROTECTOR project logos: | PROTECTOR Contract number FOOD-CT-2005-514082 TDT Recycle Reduce Reuse **3R** |
| Scientific and technical development work domain: | SCIENCE-TO-ACHIEVE-RESULTS: From applied soil science, research-technical development-innovation towards industrial application, field demonstration, agro industrial scale up and full scale technology design. |
| Project start date and duration: | March 1, 2005, Duration: 44 months |
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| Project web page: | WEB: www.terrenum.net/protector |
| Partners:<br>• Terra Humana Clean Technology Development, Engineering and Manufacturing Ltd. - coordinator (Hungary – Sweden) "TERRA"<br>• Plant Research International B.V (The Netherlands) "PRI"<br>• The University of Reading (UK) "READING"<br>• University of Rostock (Germany) "UoR"<br>• Gottfried Wilhelm Leibniz Universitaet Hannover (Germany) "LUH"<br>• Helmholtz Zentrum für Umweltforschung - UFZ(Germany) "UFZ"<br>• University of Turin – Agroinnova (Italy) "UNITO"<br>• University of Paris-XI (exit year 1 end) (France) "UPS"<br>• Migal Galilee Technologies Ltd. (Israel) "MIGAL"<br>• Consejo Superior de Investigaciones Certificas (Spain) "CSIC"<br>• Sonac Vuren BVB.V (SOBEL Group) (The Netherlands) "SONAC"<br>• ARPAD Agrar Plc. (Hungary) "ARPAD" | |
| **STATUS:** | 100% relevant to Annex 1 work description as of the detailed prepared |

| Project title: **Recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition** | |
|---|---|
| | original work plan. |

The overall goal of the PROTECTOR project was the added value upgrading and valorisation of pure organic waste streams (such as high Phosphorus containing food industrial hog animal bone meal and other agro/food industrial by-products) into high value, safe and useful products by integrated thermal inactivation and biotechnological recycling and reuse. The application driven science and technology, research and development, engineered optimization and economical industrial scale- up resulted innovative IPR-protected knowledge base and comprehensive technology.

Animal bone meal is left over from the hog food industry, which after specific thermal treatment up to 850 ºC carbonization process, contains high concentrations (>90%) of natural minerals and carbon (<10%), Calcium and Magnesium Phosphates, free from any contamination. The porous structure of the biotech specific solid carrier offers to the microbes a protected niche when introduced into soil. This product, therefore (called 'animal bone char' or 'ABC'), can be economically and efficiently used as a carrier for biological control agents or other beneficial microorganisms, whilst delivering natural P and Ca for plant growth.

The PROTECTOR process upgrades the food industrial by-products into high added value, safe, economical and efficient biological crop protection, plant growth promotion and natural fertilization products for environmentally friendly horticultural cultivations in soil and soil-less cultivations of low-input and organic farming.

During the development of the PROTECTOR product, incorporating natural fertilizer with biocontrol capabilities, the following regulation and guidelines were applied: (1) EU regulation 91/414 EEC, (2) US EPA guidelines, (3) authority product application permit test methods, regulation and recommendations.

The following 4 milestones (M) have been successfully achieved:

- In M1 animal bone waste recycling and upgrading strategies from the food industry for value-added transformation by biotechnological means were successfully developed. **Two most promising bacteria strains (Pseudomonas chlororaphis and Bacillus pumilus) and three Trichoderma harzianum fungal strains (DAR5, DAR7 and DAR14) were selected. These strains were able to grow and survive in ABC, displaying both biocontrol potential and P-mobilisation capacity.**

- In M2, Innovative Solid Substrate Fermentation and Formulation (SSFF) technology was developed, economically and technologically optimized with up to 400 kg capacity for the primary selected *Trichoderma harzianum* DAR 5 strain. The 400 kg/batch capacity innovative SSFF model equipment is already installed at the Polgardi/Hungary site.

- The M3, relating to the “modelling of PROTECTOR Phosphorus dissolution kinetics” was successfully completed. The M3 results supported and demonstrated the viability and efficiency of the product, and scientifically described the mode of actions including (1) mathematical description of dissolution kinetics, (2) predictions and process level explanations of agronomic effectiveness of PROTECTOR, (3) data sets on reactions, (4) turnover of soil organic material (SOM) fractions following PROTECTOR application to soil and (5) ability of AMF to transfer P from soil/PROTECTOR to plants.

- M4 related to the validation of PROTECTOR effects and test production of PROTECTOR formulated substances. During the 44 months project lifetime, 40 sampling protocols were made and 1270 kg ABC/ABC-formulated substance samples were shipped to the partners and used by

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TERRA for SSFF optimization test and for validation in greenhouse tests. A total of 1500 kg ABC carrier were manufactured during the project life time. 22 different types of animal bone charcoal (ABC) have been manufactured to optimize bone char surface characteristics for microbiological requirements. The ABC SM15 product has been the most successful and used for tests.

The greenhouse and field test results in the year 2006/2007, together with the 2008 field validation and demonstration tests in Hungary, Israel and Italy, demonstrated and presented the overwhelming success of the past 44 months PROTECTOR RTD Programme.

Additional authority field test programmes were executed at the sites of the Plant Protection and Soil Conservation Authority in Hungary, which is an independent governmental inspection and authority organisation. As a result of the successfully authorised test programmes they provided an official statement and product application permit proving the viability of the developed Protector technology and product.

SWOT (strengths, weakness, opportunities, threats) analyses, the cost benefit analysis (CBA) and the development of a consumer and retailer acceptance evaluation for PROTECTOR were implemented. Detailed marketing strategies were also developed.

The prime PROTECTOR dissemination strategy is the licensing program, where those partners who have innovative and industrially applicable results from science to industrialization may act as licensor (primarily P1/Edward Someus in the specific field of innovative and specific bone carbonization and solid state fermentation and formulation, where the industrial scale up of a 20,000 t/year input capacity is pre-designed, and detailed economic and market feasibility worked out. Prime market targets: IT, ES, FR, DE, NL, GR, IL, USA, AU, JP). The project contains several innovative components, which together or individually, will be industrial utilized, all standing on solid platform of advanced science knowledge base and industrial engineering.

## 1.1.1. Project execution

### *Summary of the measurable scientific and technical objectives of the PROTECTOR project*

Our technology-based, integrated recycling and upgrading strategy contains the following measurable scientific and technical objectives and relates the achievements of the PROTECTOR project to the state of the art:

**1. Development of a strategy for thermal recycling** of the **phosphorus rich** bone meal into safe and sterile animal bone charcoal, which is suitable for specific microbiological carriers. Of the 47 million tonnes of animals slaughtered for meat production in Europe every year, 17 million tonnes, minus hides, skins and bones for gelatine production, are handled by the animal by-products industry. Every year about 14 - 15 million tonnes of animal by-products are processed by renderers and fat-melters.

**As society becomes more affluent and eating habits change the proportion of an animal eaten directly is less than ever before.** The amount of by-product available for processing is, therefore, increasing. Almost all animal by-products can potentially be used to produce a useful commodity. However, to find economic markets for all by-products will depend on the scale of the operation, the cultural characteristics of the region and the distance to suitable markets. The FAO have forecast that global meat consumption will grow by 2 % per year, until the end of 2015. In 2000, EURA reported that the animal by-products industry manufactures products with an annual value of greater than EUR 2.2 billion and that this represents a very significant source of income for the European agriculture industry. To keep costs to a minimum, most have sought to place contracts with the larger rendering companies offering economies of scale. Due to fierce competition, many rendering companies went bankrupt or were bought out by the larger companies. Costs have increased for the treatment and disposal of animal by-products and this has been passed along the meat supply chain to the customer.

**The production and use of animal bone charcoal as a biotechnological solid carrier is a highly innovative carbonization method and product.** The 3R plant is the only known technology system where solid carrier thermal treatment and biotechnological systems are built together. As innovative developments in ABC carrier and SSF technology run in parallel, a coherent link has been structured between the two tasks. Therefore, the production of such innovative solid carrier or carriers requires special care and considerations, in depth scientific and technical understanding and tests.

2. **Selection of prime and second best natural soil microbial strains** compatible with Animal Bone Charcoal for (1) mobilization of the phosphorus content of the ABC carrier for plant uptake and (2) positive biocontrol effect.

3. Development and optimization of **innovative Solid Substrate Fermentation and Formulation** (SSFF) technology. The measurable objectives of the innovative SSFF technology and test equipment installation were to achieve the suitable selection of a prime microbial strain and the test production of 1500 kg SSFF formulated PROTECTOR.

4. **Assessment and mathematical descriptions of the PROTECTOR phosphorus dissolution kinetics** and the impacts of PROTECTOR on P and organic matter cycles in soil.

5. **Detailed risk assessment of all components** of the recycling process and the final product – from the bone meal through the applied microorganisms, in order to establish conclusively that there is no risk to the environment and human health.

6. **Demonstration of the PROTECTOR effectiveness** in greenhouse tests using tomato as the test plant against two economically important plant pathogens.

7. **Justification of the PROTECTOR socio-economic and technical viability** by execution of CBA, SWOT and socio-economic assessment of PROTECTOR impacts, including the evaluation of its acceptance by consumers and retailers.

7. Development of a clear product- and technology-oriented **dissemination and marketing strategy,** and a plan for increasing the PROTECTOR - technology based innovation (TBI), rapid take-up, post-project utilization, industrial scale-up and commercialization.

***Summary description of project objectives, contractors involved, work performed and end results***

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| **DEVELOPMENT OF RECYCLING STRATEGY FOR ORGANIC WASTE STREAMS<br>ANIMAL BONE CHARCOAL (ABC) CARRIER DEVELOPMENT** | | | | |
| 1 | Development of recycling/upgrading strategy for organic waste streams from the food industry. | EU and USA market was evaluated and analysed. Ongoing and future trends where PROTECTOR fits in were established. Legislative factors identified (P1, P11, and P12.) | Strategy for organic waste streams from the food industry by full chain follow up (slaughterhouse, bone meal processing, bone char processing) were identified.<br>**Strategy for thermal recycling of the phosphorous rich bone meal into safe and sterile animal bone charcoal, which is suitable for specific microbiological carrier, was developed.** | 100 |
| 1 | Food industrial organic waste material and processing characterization. | Food industrial organic waste materials and processing was characterized by P1, P11 | Food industrial organic waste materials and processing were characterized. | 100 |
| 1 | Animal bone charcoal carrier characterization | Detailed chemical analysis of the ABC was done by P1, P6 | Detailed chemical analysis of the ABC. | 100 |
| **MICROBIOLOGICAL STRAIN SELECTION** | | | | |
| 2 | Selection of bacteria compatible with Animal Bone Charcoal for phosphate mobilisation and biocontrol. | Ninety-seven bacterial isolates belonging to different species were tested for their potential to mobilize phosphate from animal bone char (ABC) by P2 PRI. Of the bacterial isolates 60 % showed positive scores. Further selection was based on growth ability and survival in ABC, as well as *in vitro* inhibition of plant pathogens *Pseudomonas chlororaphis*, and *Bacillus pumilus* were the best bacterial phosphate mobilizers in tests with ABC, followed by *Paenibacillus polymyxa*, *Burkholderia pyrrocinia* and two *Streptomyces* isolates. *In planta* tests to evaluate the biocontrol properties of twelve selected bacteria grown in ABC | Two most promising bacteria were selected: a strain of *Pseudomonas chlororaphis* and *Bacillus pumilus*. These strains were able to grow and survive in ABC, having biocontrol potential and P-mobilisation capacity. | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| | | were performed with the plant pathogens Pythium and Rhizoctonia in the greenhouse and climate room. The most potential bacterial strains concerning P-mobilisation as well as biocontrol potential were selected:<br>1. *Pseudomonas chlororaphis* 4.4.1<br>2. *Bacillus pumilus* 4.4.2<br>3. *Paenibacillus polymyxa* 12.4.11<br>4. *Streptomyces pseudovenezuelae* 13.4.2 | | |
| 2 | Selection of a capable *Trichoderma* strain compatible with ABC for mobilization of phosphorus and positive biocontrol effects. | Twenty *Trichoderma* strains of P4 UoR (*T. harzianum, T. saturnisporum, T. virirde* strains) with origin from soil and rhizosphere were used for the selection of suitable strains for Protector.<br>P4 (UoR) tested 20 *Trichoderma* strains and selected three *Trichoderma harzianum* strains (DAR5, DAR7 and DAR14), which were successful in the colonisation of ABC. The other selection criteria were: high spore production on the surface of the ABC particles, *in vitro* P mobilisation and *in vitro* antagonism. | All *Trichoderma* strains were able to grow with ABC as sole P source in solid and liquid culture.<br>The abilities of the *Trichoderma* strains to stop the growth of *Fusarium oxysporum* strains were higher than to stop the growth of *Pythium ultimum* possibly caused in part by the fast growth of this species. | 100 |
| **DEVELOPMENT OF INNOVATIVE SOLID SUBSTRATE FERMENTATION AND FORMULATION TECHNOLOGY** | | | | |
| 3 | Manufacturing of bone meal and animal bone charcoal (ABC) carrier samples for validation test. | • Bone meal were manufactured by P11<br>• ABC carrier samples with alternative qualities (cattle bone, pig bone from low to high qty) up to no 15 types of samples were manufactured by P1.<br>• **Meal air selector, to avoid abundant PAH generation under thermal treatment was designed by P1.** | P11 Manufactured of 5000 kg bone meal.<br>P1 Manufactured animal bone charcoal carrier. All total 1500kg ABC carrier were manufactured during the project life time. 22 different types of ABC were manufactured to optimized bone char surface characteristics best for microbiological requirements. ABC SM15 serial was the most successful and used for tests. (P1) | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
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| 3 | Laboratory scale optimization of solid substrate fermentation and formulation 'SSFF' process for the selected bacteria (P2-PRI) and fungi (P4-UOR) | Growth of the two selected bacteria was optimised in liquid as well as solid stage fermentation by P2-PRI. Scanning electron microscopy (SEM) pictures were prepared to visualize the growth of the bacteria inside and outside of ABC particles. Survival of the bacteria was evaluated in the dried PROTECTOR product. | Growth of the two selected bacteria was optimised in small scale solid substrate fermentation. Survival of Bacillus is perfect. Survival of Pseudomonas still has to be improved.<br>All selected micro-organisms, 2 fungi and 4 bacteria grow very well in a two stage fermentation process, based on the addition of a cheap liquid medium with proper C and N contents to the solid ABC. | 100 |
| 3 | Development of sustainable nutrient strategies for the 'SSFF' fermentation process. | Different alternative types of food industrial (molasses, corn steep liquor, tomato pulp) by-products were used as a C/N source for the microbiological growth in the 'SSFF'.<br>Technical and economical evaluation of the nutrient(s) was made before application and optimization of fermentation conditions.<br>Several nutrient combinations were tested for determination of the optimal media composition for liquid fermentation of Trichoderma strains. | Nutrient selection criteria and strategy were developed both for fungal and bacterial strains.<br>The most effective nutrient – for economical and applicability point of view was the tomato pulp. Tomato pulp was selected for liquid and solid fermentation test program and for production of PROTECTOR prototypes. | 100 |
| 3 | Industrial-like optimization and scale up of the 'SSFF' process | Two microbiological strains were used in the optimization and scale-up program in Polgardi, Hungary<br>(1) DAR5 *Trichoderma harzianu*m – selected in WP2 by P 4.<br>(2) ST4B *Trichoderma harzianum* – TERRA (P1) own strain, used as reserve strain<br>Comprehensive scientific, technical and economical modelling of the SSFF process.<br>Optimization of liquid and solid phase fermentation. | Economically and technological optimized SSFF fermentation process for the prime selected strains up to 400 kg/batch capacity.<br>Cheap industrial fermentation medium were selected. | 100 |
| 3 | Development, design, | **Development, design, manufacturing and ready** | Installed pilot SSFF model equipment with the following main | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| | manufacturing and ready installation of a 400 kg/batch innovative pilot SSFF model, which is in product like performance for primary selected *Trichoderma harzianum* strain. | **installation of a 400 kg/batch innovative pilot SSFF model, which is in product like performance**. The equipment is fully stainless steel made, including driver for agitation by 1-5 rpm. Comprehensive engineering design made, which is highly innovative. (P1) | components:<br>• Deep tank fermentor with 160 l capacity (stainless)<br>• Deep tank fermentor filter unit with 120 l capacity (stainless)<br>• Deep tank fermentor temporary storage unit with 100 l capacity (stainless)<br>• ABC mixer (stainless)<br>• SSFF formulation unit with 400 kg capacity, including discharge units<br>• Sterile air supply system and drier<br>• Pneumatic supply and transport system | |
| 3 | Research test production of PROTECTOR fermented with bacteria for the larger scale experiments. | PROTECTOR with bacteria was produced for large scale field and greenhouse experiments in 2007 and 2008; up to 20 kg (P2-PRI) | Developed solid substrate fermentation process for two selected bacteria up to 20 kg scale. | 100 |
| 3 | Research test production of PROTECTOR formulated substances by SSFF method | Two PROTECTOR prime strain prototypes were TEST produced by SSFF methods in Polgardi, Hungary by P1 (TERRA). The developed „SSFF" method is consisting of STAGE 1: Liquid phase deep tank fermentation and STAGE 2 Solid fermentation.<br>• ABC-DAR5 *Trichoderma harzianum*<br>• ABC-ST4B *Trichoderma harzianum,* for control and comparison. | The results of the SSFF tests have been clearly confirmed that the ABC is advantageous support material for microbial colonization.<br><br>The results have been demonstrated, that the developed two stage SSFF fermentation system works very well for several *Trichoderma harzianum* strains.<br><br>During the research test production 1500 kg ABC/ABC formulated substance was produced by P1. | 100 |
| **ASSESSMENT AND MATHEMATICAL DESCRIPTION OF PROTECTOR PHOSPHOROUS DISSOLUTION KINETICS** | | | | |
| 4 | Assessment and mathematical description of the PROTECTOR phosphorous dissolution kinetics and the impacts of PROTECTOR on P and | The following task were executed by P3, P4 and P5:<br>• Mathematical description of dissolution kinetics of PROTECTOR. Predictions and process level explanations of agronomic effectiveness of PROTECTOR<br>• Data sets on reactions and turnover of Soil | The main results were the predictions and process-level explanations of agronomic effectiveness of PROTECTOR.<br>In a direct comparison with GPR, which is well-characterised and widely accepted as a relatively soluble phosphate rock, ABC was better in providing available P, assessed by the Olsen method. It could even supply some available P immediately after application to soils of high | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
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| | organic matter cycles in soil. | Organic matter (SOM) fractions following PROTECTOR application.<br>• Data sets on the ability of arbuscular mycorrhizal fungi (AMF) to transfer P from soil/PROTECTOR to plants.<br>• Characterization of microbial biomass and functionality. | pH, in which GPR was ineffective. Thus ABC has a wider range of application than PR. | |
| 4 | Elucidation of the 'P-bridge' functions of arbuscular mycorrhizal fungi (AMF) between the PROTECTOR and host plant. | The general approach to investigate the P-bridge function of AMF between ABC particles and plant roots was to grow different plants in greenhouse experiments offering no other P-source than the ABC material. Contractor involved: P5. | The results clearly documented the ability of arbuscular mycorrhizal fungi to extract P from ABC material and deliver it to their host plants.<br>AMF can supply plants with P from ABC particles via their extra radical hyphae acting as a P-bridge.<br>MF isolate could be selected that can be used together with biocontrol micro-organisms in combined applications without any disadvantages. | 100 |
| **DETAILED RISK ASSESSMENT OF ALL COMPONENTS OF THE RECYCLING PROCESS AND THE FINAL PRODUCT** | | | | |
| 5 | Development of a rational approach for a risk assessment strategy for the agricultural use of material based on animal bone char; | Integrated risk assessment scheme that covers both ecotoxicological and human health aspects associated with using ABC as fertilizer and plant protection product were developed by P6. | Targeted ecotoxicological test strategy has been developed for the risk assessment of ABC material. | |
| 5 | Risk assessment of the meat industrial Technical By-product concerning TSE | The following three parts of the BSE Risk assessment were evaluated:<br>1- Risk assessment of input material (i.e. estimate infectious load in applied MBM).<br>2- Risk reduction due to processing into product and cross-contamination risks.<br>3- Risk at use as fertilizer on various crops.<br>Contractors involved: (P2 - PRI) | The final conclusion of the assessment was that the risk of transmitting BSE to cattle or humans via the use of PROTECTOR on crops is negligible, both for human food and for cattle feed. | 100 |
| 5 | Safety evaluation of selected micro-organisms | Safety of the selected bacteria and fungi were evaluated on the basis of literature and registration of similar strains. Material Safety Data Sheets were | **All selected isolates were non-GMO, and isolated from natural agricultural fields within Europe.**<br>The selected 4 bacteria and fungi belong to safety class 1 following | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| | | prepared for the selected micro-organisms. Basic safety and registration information was gathered. (P2-PRI, P4-UOR) | 2000/54/EC Regulation. No harm is expected for humans to work with these strains. These bacteria and fungi can be used under standard safety regulations.<br>A Material Safety Data Sheet (MSDS) has been developed for the four bacteria and fungi. | |
| 5 | Chemical analysis of ABC material | More than 10 different batches of the ABC material and sub samples were chemically and ecotoxicologically analysed in the laboratories of the UFZ to identify the most critical contaminants and to estimate the quality of the different ABC batches. (P6-UFZ) | Quality assessment of the different ABC batches.<br><br>The ABC carrier is safe for soil application. | 100 |
| 5 | Ecotoxicological Characterization of the ABC material. | The ecotoxicological assays used in the risk assessment were selected on the basis of their scientific meaningfulness and their current or future acceptance by regulatory institutions in the different European countries. (P6-UFZ)<br><br>Using the bioassays ranging from soil bacteria, luminescent bacteria to microalgae, from Daphnia, zebrafish embryos, earth worms to higher plants, a wide range of ecologically relevant organisms was analyzed. (P6-UFZ) | Overall the quality of the ABC material was so good, that acute effects in the different analyzed test organisms and test conditions could not be observed. Effects on soil microflora could not be seen also. There was no toxicity to earthworms observable.<br>No mutagenicity and toxicity of the PROTECTOR substance were found. | 100 |
| 5 | Evaluation of the impact of the PROTECTOR on the soil microflora | The impact of PROTECTOR (animal bone charcoal with the microorganisms) on the soil microflora was evaluated. The aim of this task was to analyze the potential shifts in the bacterial and fungal populations in soil due to the application of PROTECTOR. Community structures of fungi and bacteria can be compared by the use of PCR-DGGE techniques. (P4) | The influence of the PROTECTOR product (i.e. ABC fermented with microorganisms) on general soil communities was little. As a consequence, the environmental risk of this product is low. | 100 |
| **VALIDATION OF PROTECTOR EFFECTS** | | | | |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| 6 | Validation of PROTECTOR effects | (1) Effects of PROTECTOR on soil borne pathogens in greenhouse were evaluated.<br>(2) Mode of action of PROTECTOR was identified.<br>(3) Qualitative and quantitative evaluation of effects of PROTECTOR crop development and yield were executed.<br>Two formulations of ABC (ABC SM 7, ABC SM 15) and seven formulations of Protector (ABC SM 15 + microorganisms: DAR 7, DAR5, T22, *Paenibacillus polymixa, Pseudomonas chlororaphis, Bacillus pumilus, Streptomyces pseudovenezuelae*) were tested on small, semi field and field scales.<br>ABC and Protector were tested for their efficacy in different simulated conditions, both at nursery stage and growing stage directly in the soil, against *Fusarium oxysporum* f.sp. *radicis lycopersici* and *Pythium* sp. on tomato.<br><br>Totally were carried out:<br>• 7 laboratory tests;<br>• 12 trials in greenhouse;<br>• 5 field trials.<br>Contractors involved: P2, P7, P9 | (1) PROTECTOR was stimulated and increased the active microbial biomass, were competing consequently with the pathogen for space, carbon and other nutrients;<br>(2) PROTECTOR was applied as a carrier of beneficial microorganisms, such as *Trichoderma* spp., that are able to directly parasitize pathogens, produce antibiosis substances inhibiting pathogens, colonize harmful propagules and reduce the disease potential;<br>(3) PROTECTOR enhanced phosphorus availability in the soil, providing slow releasing of the nutrient, root development, early flowering, ripening and fruit quality;<br>(4) PROTECTOR enhanced nutrient availability in the soil and, consequently, is responsible to induce disease resistance in the plant. | 100 |
| 6 | Detection of the introduced micrroorganisms | Development of selective detection technique for detection of introduced organisms within a complex microbial population. (P2) | A detection system was successfully developed for Pseudomonas, which showed extremely good root colonizing capacities of this strain in greenhouse experiments. Detection of Bacillus in the vicinity of complex microbial populations is not possible yet. | 100 |
| 6 | Biological efficiency investigation of Protector substance | Additional Authority efficiency trials of the PROTECTOR substance were executed. | Protector treatments (600 kg/ha, 1000 kg/ha) influenced favourably the soil structure. No phytotoxic changes were observed during the Authority test programme.<br>It can be stated that Protector in all rates favourably influenced the yield | 100 |

| WP | Project Objectives | Work performed<br>Contractors involved | End results and<br>Main achievements | Degree (%) |
|---|---|---|---|---|
| | | | results.<br>Recommended Protector dose: 1000 kg/ha. | |
| **JUSTIFICATION OF PROTECTOR SOCIO-ECONOMIC AND TECHNICAL VIABILITY** | | | | |
| 7 | Justification of Protector socio-economical and technical viability by execution of CBA, SWOT and socio-economic assessment of Protector impacts, including the evaluation of its acceptance by consumer and retailers. | SWOT (strengths, weakness, opportunities, threats), CBA and consumer retailer acceptance evaluation. Socio-economic analysis and feasibility of PROTECTOR.<br>Contractors involved: P7, P4, P1, P11 | Detailed SWOT, CBA and consumer retailer acceptance evaluation of PROTECTOR end product and its application were executed. | 100 |
| **DEVELOPMENT OF CLEAR PRODUCT- AND TECHNOLOGY-ORIENTED DISSEMINATION AND MARKETING STRATEGY** | | | | |
| 8 | Development of dissemination technology transfer plan and marketing strategy and management of dissemination program. | Efficient dissemination, technology transfer plan and marketing strategy were developed including efficient management of dissemination program. | The consortium participated at international conferences and made several oral presentations related to the PROTECTOR RTD programme. Four newsletters have been issued and circulated in English and Hungarian language.<br>The Consortium was in continuous contact with the HUNGARIAN NATIONAL AUTHORITY for SOIL and PLANT PROTECTION.<br>4 languages and abstract information on PROTECTOR project were linked to the PROTECTOR web site.<br>WEB PUBLICATION: http//:www.terrenum.net/protector. WEB and electronic communications | 100 |

### *The strategic impacts of the project on its industry and research and research sector*

**The innovative 3R "Recycle-Reuse-Reduce" PROTECTOR technology provides recycling of agricultural organic and mineral by-products for soil amendment and restoration of soil natural balance.** The input feed stream is refuse grain, food processing and/or other by-products. The innovative technology provides surface modified charcoals and minerals for improved plant availability. The process is upgrading by-products to high added-value plant growth promotion and natural fertilization products for environmentally friendly vegetable cultivation, with carbon sequestration potential. The 3R is a horizontally arranged and indirectly heated low temperature zero emission carbonization system (operating under vacuum, up to 850 °C$^{\pm 50°C}$ material core temperature) and directly integrated novel agro biotechnological processing units of specific solid state fermentation and formulations.

**The PROTECTOR project provides solid Trans-European knowledge-base innovative technologies for recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition which contributes to the competitiveness and sustainability of major European Eco-industries and bio-based economy. The PROTECTOR measurable, justified and verified scientific and technological achievements will open new technical and economical perspectives for the competitive European vegetable production industry, resulting in safer, higher quality and less costly vegetables for the Consumer.**

The project's essential role in the recycling and transformation of food chain organic waste into added-value products, by advanced biotechnological methods, provides **new dimensions of change "from quantity-to-quality"**. PROTECTOR will realise Consumer-demanded "farm-to-fork" vegetable and food products that are both safe and affordable. Considering the fact that vegetables are the second most important food supply after dairy products in the EU, the PROTECTOR activities will strengthen the scientific and technological knowledge base that is required to improve the health and well-being of European citizens; this will be achieved through a higher quality of food, improved control of food production practices and of related environmental factors.

A side effect of sustained heavy P fertilizer additions can be the accumulation and introduction into the human food chain of heavy metal contaminants contained in fertilizers. Phosphate fertilizer use has caused small but significant increases in soil cadmium levels. These inputs are of a magnitude similar to those from the atmosphere in industrialised countries. There are still no agreed safe Cd limits for soils, but it appears that concern about Cd build-up in soils may be warranted only where several critical factors combine, i.e. on acid soils with low cation exchange and low P fertility, to which significant P fertilisation is applied as low grade fertilizer or rock phosphate, particularly to Cd accumulators like leafy vegetable crops, and where the produce is the main source of local food consumption. **Phosphorus containing fertilisers can contain high levels of cadmium depending upon the source of rock phosphate used in manufacturing**. Trace element fertilisers and phosphogypsum may also contain high cadmium levels. **Consequently, these chemosynthetic fertilisers can be a major source of cadmium in horticultural soils.**

Reasons for looking at alternative and renewable sources of phosphorus (P) for agriculture and horticulture include the near future depletion of economically recoverable low Cadmium/Uranium content phosphate rock (PR) reserves and the need to restrict introduction of toxic metals to agricultural soil via fertilizer, for which animal bone is a clean P source. For example, reviews show that cadmium concentrations range up to only 3.03 mg kg$^{-1}$ in cattle and pig bone (Doyle 1979) but up to 556 mg kg$^{-1}$ in PR (Van Kauwenbergh 1997). However, concerns have arisen about the transmission of diseases through animal by-products and in the European Union regulations control their disposal (EU 2002). Controlled thermal treatment exceeding about 400$^{o}$C can be used to make a form of biochar that is free of infective

agents, rich in P, and that we call animal bone char (ABC). ABC appears potentially an effective P fertilizer but, prior to the current project, had not been tested for this purpose.

The project impact on the agricultural sector and crop protection in particular, is really important for several reasons.

- PROTECTOR is a new organic fertilizer that can replace polluting and hazardous phosphate fertilizers offering farmers the opportunity to fertilize their crops and increase at the same time food quality and security.
- The microorganisms showed to efficiently control soil-borne plant pathogens and can be considered as a new tool for crop protection. The recent pesticide bans set by EU, in particular for crops like small fruits and vegetables, will promote the use of more environmental friendly practices in the crop protection field. PROTECTOR has a promising role in such regard, giving farmers a new tool for controlling soil-borne pathogens.
- PROTECTOR combines several effects on plants: nutrient supplier and carrier for biological control agents. This combination of effects strengthens the efficacy of the product and represents a new and innovative product in the agricultural sector.

As such, major benefits can be expected from the use of PROTECTOR in organic and low input farming agriculture, particularly in vegetable and medical herb plant cultivation:

- Biological control effect against soil borne plant pathogens, for substitution or significantly lowering of the input of agro chemicals.
- Plant growth promotion, for natural substance support to achieve higher plant yields with better quality and safer products.
- Natural fertilization: Food crop mineral deficiency and disturbance stress mitigation in temperate climate regions by restoration of soil natural balance. Substitution of highly energy intensive artificial fertilizers.

### *PROTECTOR benefits and impacts*

OVERALL BENEFITS:

- Mitigation of mineral and nutrient deficiency stress of the food crops, restoration of the natural balance and functionality of degraded continental agro soils in temperate climate regions, with controlled microbiological activity and precision nutrient supply for sustainable, improved, economical and ecological food crop production.
- It is consistent with principles of organic production.
- Prevention of nutrient loss-, ABC helps to reduce nutrient run-off from soils and the associated problems of eutrophication.
- Supporting beneficial soil life forms towards balanced living soil. Improving soil fertility and stimulating the roles of plants and microbes in natural soil processes. Essential for obtaining, maintaining and increasing the fertility and biological activity of the soil or to fulfil specific nutrition requirements of crops.
- It has positive impacts on soil organisms and/or the physical characteristics of the soil.
- It encourages soil organisms and mycorrhiza fungi, which can produce many compounds that help plants, including substances such as citrate and lactate that combine with soil minerals and make them more available to plant roots.
- Soil conditioning.

PROTECTOR ENVIRONMENTAL BENEFITS

- Efficient use of nutrient inputs in agriculture for efficient GHG mitigation.
- Providing more conservation-oriented agriculture management practices.
- It has a positive effect on biodiversity.
- Supporting environmentally-orientated farming, development of environmentally compatible agriculture practices with maintaining the nutrient balance of the soil.
- Prevention of groundwater pollution
- Reducing direct and indirect energy use to avoid carbon emissions.
- Increasing renewable energy production to avoid carbon emissions. Biomass energy can be used to avoid greenhouse gas emission by providing equivalent energy for heat and electricity generation, and for transportation fuel. If biomass is harvested and burned, and the same area replanted or regenerated, there are no net carbon emissions over the harvest cycle.

PROTECTOR ECONOMICAL BENEFITS

- Improved farm income per farmer from increased tons/hectare, which is leading to rural social improvements and gender equality.
- Reduced per hectare expenditures on fertilizers, therefore less pressure on increasingly limited oil and natural gas supplies - leading to lowered fuel costs.
- Improved rural employment opportunities.

PROTECTOR APPLICATION BENEFITS:

- Improved protection of subsurface water resources from less fertilizer runoff.
- Nutrient balance and slow release fertilizers.
- Biological and chemical methods for manipulating soil microbial processes to increase efficiency of nutrient uptake, suppress N2O emissions, and reduce leaching.
- Promotion of increased plant growth.
- Increased use of all the non-dispatchable renewables (wind, PV, biomass, etc), as facilities provide much of the required backup (heaviest char and electrical output during peak electrical demand periods - in West it is July - August for air-conditioning).
- The ABC stimulates indigenous arbuscular mycorrhiza fungi in soil and thus promotes plant growth
- ABC and its cellular structure may provide habitat for this beneficial bacterium. Porous substance with high water and air holding capacity; Suitable habitat for some microbes and plant growth, good material for soil amendment, absorption of chemicals and humidity control.
- High alkalinity; neutralization of acidic soil and improvement of chemical components of soil and selection of microorganisms
- ABC as media for immobilizing useful microorganisms (spores of bacteria, root nodule bacteria, mycorrhizal fungi.

The results of the PROTECTOR project will **improve the traditional European strength of food production and farming systems**, where the continued competitiveness will be ensured by sufficiently large PROTECTOR end product price cuts that will guarantee the growth of sustainable low input farming and competitive agriculture sectors without being subsidized. In this context PROTECTOR provides methods and products which are sound and environmentally friendly, able to supply quality products of the kind the public wants, and supports diverse forms of agriculture, which are not just output but rather recycling**,** reuse and reduce oriented, while applying prevention, protection and preservation concepts as well.

**From a macro-economic point of view, investment in the agriculture sector can be crucially important:**

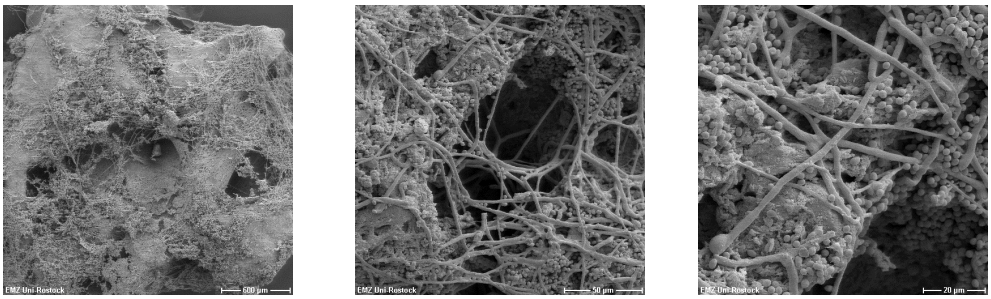
- The high proportion of the population engaged in agriculture, as farmers in their own right, as labourers, or as entrepreneurs or employees in input supply, processing or marketing.
- The high contribution of agriculture to the national economy, with high employment and income multipliers, making it a foundation for general economic development in many countries.
- The trade in agricultural products, whether domestic or international, in some countries constitutes a high proportion of overall trade.

**Impact of PROTECTOR project on research sector:**

1) All Partners have generated individual excellence in the relevant specific scientific areas.
2) The developed PROTECTOR technology for transformation of food chain waste into a high added value healthy and safe product ("turning trash into cash") is technically, environmentally and economically very effective. At a lower overall waste management cost, a higher value is achieved; i.e., a profitable operation that is less costly than any other known comparable solutions.
3) Combined and complementary scientific excellence, including fundamental biotechnological advances, has been achieved across 7 countries during the execution of the project.
4) The "cross-fertilization" links between Universities and the industrial sector have been strengthened and Trans-European cooperation networking has been implemented.
5) The consortium has translated a scientific knowledge into new products with measurable and justified benefits for the Consumers and society as a whole.
6) The results of the PROTECTOR will contribute to the creation of new skilled jobs, especially in the SME sector in rural areas and for women, thus contributing to a more equitable society.
7) We attract and train researchers and new resources for the subject.
8) The results of the PROTECTOR project can support the EU policy development for improved recycling of organic waste from the food industry, crop protection and food safety.
9) The consortium has provided a balanced and responsible legal and regulatory framework for all Partners from RTD to Consumers in the program.
10) An efficient technology transfer and wide dissemination plan has been implemented in the European dimension.

**Growth of *Trichoderma* strains on ABC** (observed with REM)

Outside of the ABC particles



Inside of the ABC particles

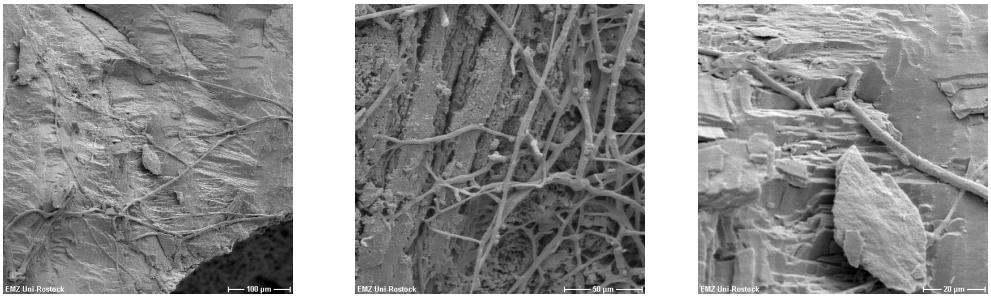


**Figure 1:** Raster electron microscopic (REM) pictures of *Trichoderma harzianum* colonising the outside and inside of ABC (cattle) particles with mycelial growth in the inside and spore production on the outside

### 1.1.2. Dissemination and use

Publishable results of the Final plan for using and disseminating the knowledge
Publishable exploitable results:

Result description (product(s) envisaged, functional description, main advantages, innovations)

**The PROTECTOR technology for recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition**

- methods for optimization of solid carrier based soil fungus microbiological substances
- methods for scale up of solid carrier based soil fungus microbiological substances
- methods and apparatus for solid state fermentation technology
- methods and apparatus for solid state formulation technology

P1 is one of the leading companies in the area of international carbonization, solid state fermentation and formulation science and technology; it provides an original source of knowledge and an industrial engineering base. The specific bone char thermal treatment technology developed and designed by P1 is the only one known on the international market which can produce the bio specific bone char solid carrier. The integrated bone char and biotech processing technology is the only one known on the international market with specific performance.

**The production and use of animal bone charcoal for biotechnological solid carrier is a highly innovative carbonization method and product.** The PROTECTOR is the only known technology system, where solid carrier thermal treatment and biotechnological systems are built together. As Animal Bone Charcoal (ABC) carrier development and Solid Substrate Fermentation and Formulation (SSFF) technology innovative developments run in parallel, a coherent link has been structured between the two tasks. Therefore, the production of such innovative solid carrier or carriers requires advanced knowledge, special care and considerations, in depth scientific and technical understanding and tests. **Selection of prime and second best natural soil microbial strains** compatible with Animal Bone Charcoal for (1) mobilization of the phosphorus content of the ABC carrier for plant uptake and (2) positive biocontrol effect. **Innovative Solid Substrate Fermentation and Formulation (SSFF) technology has been developed and optimized**.

During the applied scientific RTD and application oriented optimization, the PROTECTOR products have been successfully multiple tested for several years under different climatic, soil and agro-industrial true value production conditions in Hungary, Israel, Italy, Germany and The Netherlands. The EU relevant permitting field tests have been completed at the end of 2008.The results have clearly indicated the positive PROTECTOR efficiency under different field condition. **The PROTECTOR open ecological field Application Permit has been received in 2009. Permit Number:** 02.5/97/7/2009.

The output PROTECTOR end product provides the following combined effects:

1. Plant growth promotion, for natural substance support to get higher plant yields with better quality and safer products.
2. Biological control effect against soil borne plant pathogens, for substitution or significantly lowering of the input of agro chemicals.
3. Natural fertilization: Food crop mineral deficiency and disturbance stress mitigation in temperate climate regions by restoration of soil natural balance. Substitution of highly energy intensive artificial fertilizers, including substitution of the Cadmium and Uranium heavy metal contaminated phosphate rock fertilizers.

**Possible market applications (sectors, type of use) or how they might be used in further research (including expected timings)**

**Targets:**

- Organic vegetables, herbal and medicinal plant production
- Low input farming
- Farming in ecologically and environmentally sensitive areas
- Integrated farming

**Stage of development: prototype**

**Status of the development:**

Innovative Solid Substrate Fermentation and Formulation technology and "product like" pilot plant has been developed for effective formulation of several types of microbiological substances on soil application specific chars and minerals during the FP6 PROTECTOR project. Scale up optimization and comprehensive industrialized engineering design developed for 30,000 $m^3$/year input feed stream, including biochar specific auxiliary systems for turn key installation as of modern US/EU industrial standards. The EU relevant four years permitting field has been completed.

**Market and economical analysis results show very positive trends for the PROTECTOR.**

**Collaboration sought or offered (manufacturing agreement, financial support or investment, information exchange, training, consultancy, other):** After years of RTD, advanced engineering, validation and field demonstration works the PROTECTOR technology is ready to be licensed and to implement full scale industrial and production systems.

Offered collaboration:

- License agreement
- Marketing agreement
- Manufacturing agreement
- Joint venture agreement

## Collaborator details:

The Terra Humana provides practical applied research and engineering design „ready to commercialize" results which has potential international commercial interest and strategies for how to exploit it. The status of the 3R Carbonization technology is post development, proven and demonstrated with clearly achieved industrial phase.

**PROTECTOR licensing considerations:**

- **Juridical and financially clean and clear, transparent and documented legal status.**
- **Original technology**, which is also including several novel part solutions.
- **Patented solution**, but the key components are still protected by confidential, non public know how and design.
- **Comprehensive technology design, protected by confidential and non public full scale engineering system**, which has been designed in both traditional drawing style and AUTOCAD 3D INVENTOR in very detail, as of manufacturing execution design.
- The PROTECTOR process control, electric and electronic installations are based on the Japanese OMRON software and hardware, which is fully compatible with all major industrial electronic

systems, including Honeywell, Rockwell Automation - Allen Bradley, Siemens, Endress+Hauser and Burr Brown.

- **The PROTECTOR meets all EU and US industrial norms and standards** and also prepared for stricter environmental normative changes beyond 2012.The inventor Edward Someus is providing long termed cooperation and world-wide technical support + skilled know-how service, training and license maintenance for implementation and systematic operations.
- „**Value for Money" by the combination of reasonable License and Royalty Fees.**

Intellectual property rights granted. The Protector technology is an original, patented and intellectually property right protected full scale industrial engineering and design solution.

Contact details

| | |
|---|---|
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## *1.2. Final plan for using and disseminating the knowledge*

The overall goal of the objective driven PROTECTOR project was to develop, optimize and industrial scale up realize the integrated thermal inactivation and biotechnological recycling of high phosphorus containing non-SRM organic waste (bone meal) and upgrade it into a high added value and safe biotechnological crop protection and nutrition product.
Based on the past 44 months scientific and technical development of the project, and the very successful 2006/2007 and 2008 test and Authority test results the PROTECTOR project presented overwhelming success. In Hungary the field tests were executed at the Plant and Soil Protection Authority sites, which in independent governmental organization. They have provided official statement about the field viability the PROTECTOR products and methods.
The prime dissemination strategy is the licensing program, where those partners who have innovative results from science to industrialization may act as licensor (primarily P1 in the specific field of bone carbonization and solid state fermentation and formulation). The PROTECTOR project contains several innovative components, which together or individually, can be utilized.

As the prime objective for using and disseminating the knowledge is towards industrial application of the results under commercial conditions, several components of the knowledge were CONFIDENTIAL, including, but not limited to, all parts and components related to the carbonization and manufacturing of solid carrier, SSFF and all its adaptations, developed, designed and engineered by P1.

The Consortium Agreement ANNEX B and other relevant parts in the agreement are important confidential elements. Therefore all publications must be pre permitted by the Coordinator and owner of the Annex B. 30 days before any publications, full set of publication documentation to be submitted to the Coordinator for discussion and evaluation if confidentiality interest is not damaged.

**It is clear for all Partners that scientific publications were not goals for the PROTECTOR project, but rather instruments** to demonstrate the scientific, technical and economical viability of the developed innovative product and technology. Therefore, their targeted audience was quite diversified, eg. Agro industrial partners, farmers, investors, research – academics and educational communities, authority and legislative people as well, which 2008 visibility programmes were scheduled as of Annex I.

Partners were encouraged to develop scientific publications, that is providing picture of the partners own activities undertaken, however these publications may not contain confidential information, data and results, but rather support the “product like” PROTECTOR development.

## P1 TERRA

Section 1

Beyond the bone meal specific carbonization method and apparatus innovations at least four additional innovative components are under preparation, which are under extensive processing, namely:

- methods for optimization of solid carrier based soil fungus microbiological substances
- methods for scale up of solid carrier based soil fungus microbiological substances
- methods and apparatus for solid state fermentation technology
- methods and apparatus for solid state formulation technology

Exploitable knowledge and its Use:

| **Exploitable Knowledge (description)** | **Exploitable product(s) or measure(s)** | **Sector(s) of application** | **Timetable for commercial use** | **Patents or other IPR protection** | **Owner & Other Partner(s) involved** |
|---|---|---|---|---|---|
| methods for optimization of solid carrier based soil fungus microbiological substances | solid carrier based soil fungus microbiological substances | Agriculture & Horticulture | 2010 | P1 | TERRA |
| methods for scale up of solid carrier based soil fungus microbiological substances | solid carrier based soil fungus microbiological substances | Agriculture & Horticulture | 2010 | P1 | TERRA |
| methods and apparatus for solid state fermentation technology | solid state fermentation technology | Biotechnological Industry | 2010 | P1 | TERRA |
| methods and apparatus for solid state formulation technology | Solid state formulation technology | Biotechnological Industry | 2010 | P1 | TERRA |

Section 2

- WEB and electronic communications
- presenting on conferences and scientific journals

Type of audience: agro industrial partners and farmers, commercial investors, authority people, legislative people who are preparing future normative, research and educational community.

**Details about the publications:**

- HUNGARY FOR FP6, January 2008. No. 1, http://hufp6.tetalap.hu/docs/HUFP6_21.pdf
- E Someus, "**Plant derived feed additive: recent scientific results and regulatory development, successful EU projects and partners for scientific cooperation**" FEED –SEG Symposium, January 14-15, 2008, Hungary**,** http://www.matchmaking.at/feedseg/. International conference presentation: FEED –SEG, January 14-15, 2008,Mosonmagyarovar, Hungary, http://www.matchmaking.at/feedseg/
- International conference presentation: BIOCHAR, September 8-10, 2008, Newcastle-Gateshead, UK, www.biochar-international.org
- J Postma, E Nijhuis, F Clematis, E Someus, "***Recycling and upgrading of bone meal for environmentally friendly crop protection and phosphate fertilization*"**ORBIT Conference, October 13-15, 2008, Moving Organic Waste Recycling Towards Resource Management and for the Biobased Economy, Wageningen, The Netherlands. Wageningen University Research, Plant Research International B.V, P.O. Building nr. 107, Droevendaalsesteeg 1, 6708 PB Wageningen, The Netherlands http://www.orbit2008.de
- E. Someus, ***Food crop mineral deficiency and disturbance stress mitigation in temperate climatic regions by economical and environmental valorization of agricultural by-products,*** Nova Science , New York, 2009.
- Web: https://www.novapublishers.com/catalog/product_info.php?products_id=8372
- E. Someus, ***Recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition: the PROTECTOR project***, Handbook of waste management and co-product recovery in food processing. Volume 2. Chapter 23. Edited by Keith W. Waldron, Woodhead Publishing 2009.

Section 3

N**egotiations made with SONAC Vuren P11 partner** (Europe's only one bone processing specialized industry with 150,000 t/y production capacity) **for licensing and industrialization set up of the PROTECTOR technology in the Netherlands.**

The reality of the industrial licensing of the P1 Terra Humana Ltd / Edward Someus results as dissemination target is based on the following archived results:

- P1 is one of the leading international carbonization, solid state fermentation and formulation science and technology original source knowledge and industrial engineering base.
- The specific bone char thermal treatment technology developed and designed by P1 is the only one known on the international market which can produce the bio specific bone char solid carrier.
- The integrated bone char and biotech processing technology is the only one known on the international market with specific performance.
- P1 bone char, solid state fermentation and formulation and field demonstration test programmes are "product like", which performance is the only way to convince potential commercial investors and licensors to enter on board for utilization of the results. (Commercial investors are not really interested in theoretical and lab results, which are too far away from the application field reality.)
- Market and economical analysis results showing very positive trends for the PROTECTOR.
- 20,000 t/y throughput PROTECTOR industrial production base unit has been pre designed, by P1 which is the world largest bone char and soil biotech processing industrial set up, not to talk about the only one available output quality production performance.

## P2 PRI

section 1

The bacterial (and fungal) strains to be selected will be an exploitable result.
Bacterial strains can not be patented, but their commercial use can be protected by a Safe deposit or a deposit under the Budapest Treaty. The application and the production methods of the bacterial (and fungal) strains with ABC can be patented. However, it is too early to give detailed information on this point at this moment, as Edward Someus has a patent on that already.

Exploitable knowledge and its Use:

| **Exploitable Knowledge (description)** | **Exploitable product(s) or measure(s)** | **Sector(s) of application** | **Timetable for commercial use** | **Patents or other IPR protection** | **Owner & Other Partner(s) involved** |
|---|---|---|---|---|---|
| Bacterial strains with known properties to control plant diseases and to dissolve P | Bacterial strains | Agriculture & Horticulture | 2010 | - | PRI is owner of the strains.<br>Agronomic knowledge is owned by several partners |
| Production of bacteria in ABC (small scale) | Upscaling of production | Industry for producers of micro-organisms | 2009 | - | PRI & TERRA |

Overview table on dissemination of knowledge:

| **Dates** | **Type** | **Type of audience** | **Countries addressed** | **Size of audience** | **Partner responsible /involved** |
|---|---|---|---|---|---|
| 2006 | Website abstract | all | Dutch language | | PRI |
| 22-5-2008 | Poster | Research | NL | 150 | PRI |
| 22-5-2008 | Flyer | Research & Companies (Agriculture) | **NL** | 100 | PRI |
| 22-5-2008 | Publication of Abstract Dutch Crop Protection | Research & Higher education & Companies (Agriculture) | **NL** | 600 | PRI |
| 14-10-2008 | Oral presentation International symposium ORBIT | Research & Industry (organic residues) | **World-wide** | 300 | PRI |
| 14-10-2008 | Publication of Abstract (book + CD) ORBIT | Research & Industry (organic residues) | **World-wide** | 300 | PRI |
| Beginning 2009 | Publication on the selection of microbes (peer reviewed English journal) | Research & Industry | World-wide | | PRI |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| Beginning 2009 | publication on biological control of plant diseases using ABC with the selected bacteria (peer reviewed English journal) | Research & Industry | World-wide | | PRI |

**Details about oral presentations and other communications**

- Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Recycling and upgrading of bone meal for environmentally friendly crop protection and phosphate fertilization. 6th International Conference Moving Organic Waste Recycling towards Resource Management (ORBIT), 13-15 October, Wageningen, NL
- Communication of the project to the "Cradle to Cradle" initiative in the Netherlands. This is about re-use of materials
- Communication and Presentations to other researchers within Plant Science Group, WUR
- Communication with composting companies
- Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Een nieuwe carrier voor biologische bestrijders. Gewasbeschermingsmanifestatie, 22 May, Ede, NL

**Details about the publications**

- Crop protection journal in Dutch: Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Een nieuwe carrier voor biologische bestrijders. Gewasbescherming 39:36S.
- Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Recycling and upgrading of bone meal for environmentally friendly crop protection and phosphate fertilization. In: L. Rodic-Wiersma, J. Barth, W. Bidlingmaier, M. de Bertoldi & L.F. Diaz (Eds.), Conference Paper Summaries, 6th International Conference Moving Organic Waste Recycling towards Resource Management (ORBIT), p. 91.

## Details about the scientific publications which will be submitted in the near future

- A publication will be submitted (2009) on the selection of microbes (peer reviewed English journal)
- A publication will be submitted (2009) on biological control of plant diseases using ABC with the selected bacteria (peer reviewed English journal)

An abstract was delivered to attend the following congress:
ORBIT the 6th biannual Conference on Organic Residues Recycling ORBIT2008 (13-15 October 2008, Wageningen), entitled: Moving Organic Waste Recycling towards Resource Management and the Biobased Economy. (www.orbit2008.de )
This conference was dealing with several relevant research topics such as renewable energy, biogas, waste management, soil protection, global warming, carbon sequestration, bio-based economy, organic farming, etc.
Poster presentation: Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Een nieuwe carrier voor biologische bestrijders. Gewasbeschermingsmanifestatie, 22 May, Ede, NL

## P3 READING:

Exploitable knowledge and its use

| **Exploitable Knowledge (description)** | **Exploitable product(s) or measure(s)** | **Sector(s)** of application | Timetable for commercial use | Patents or other IPR protection | **Owner** & Other Partner(s) involved |
|---|---|---|---|---|---|
| 1. Knowledge of soil conditions that enable ABC (Animal Bone Charcoal) to be used as a P fertilizer | ABC used as a P fertilizer | Agriculture, horticulture, floriculture | Depends on results obtained by other Project Partners | Depends on results obtained by other Project Partners | P3 (Reading), P1 (Project co-ordinator) |
| 2. Knowledge of influence of ABC particle size on use of ABC as a P fertilizer | ABC used as a P fertilizer | Agriculture, horticulture, floriculture | Depends on results obtained by other Project Partners | Depends on results obtained by other Project Partners | P3 (Reading), P1 (Project co-ordinator) |

Exploitable result 1:
This knowledge shows that the more acidic a soil is, the ABC is more effective. Thus it will be possible to indicate which soils will give the best results for crop P nutrition by ABC and PROTECTOR.
Partners P1, P7, P9 and P12 might be most involved in the exploitation of this knowledge, since it is concerned with the agronomy of use of the product.
Exploitation will depend on outcomes in field trials, cost-benefit and socio-economic assessment (dealt with in other work packages).

Exploitable result 2:
This knowledge shows that ABC is more effective if its particle size is made smaller. Thus its bioavailability might be altered for particular applications. This knowledge needs further testing and research, in collaboration with partners manufacturing ABC so that manufacturing methods are feasible. Partners P1 and P11 might be particularly involved with development of this knowledge, being the manufacturers of the material. Testing with plants is also needed, requiring expertise of Partners P7, P9 and P12.
Exploitation will depend on outcomes in field trials, cost-benefit and socio-economic assessment (dealt with in other work packages).

Overview table on dissemination of knowledge

| **Planned/actual Dates** | **Type** | **Type of audience** | **Countries addressed** | **Size of audience** | **Partner responsible /involved** |
|---|---|---|---|---|---|
| 07-02-2007 | Oral presentation at Rothamsted Research Institute, Seminar | Research | UK | ~50 | READING |
| 07-02-20078 | Oral presentation at Forest Research Institute, Seminar | Research | UK | ~20 | READING |
| 20-10-2008 | Oral presentation at University of Reading, School of Human and | Research | UK | ~40 | READING |

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | Environmental Sciences | | | | |
| Nov 2008 | Peer-reviewed paper accepted for publication in Nutrient Cycling in Agro-ecosystems (Dissolution of Phosphorus from Animal Bone Char in 12 Soils) | Research | International | | READING |
| 2009 | Peer-reviewed paper on the relationship between the extractability and speciation of soil organic C and P | Research | International | | READING and ROSTOCK (UoR) |
| 2009 | Peer-reviewed paper on the effects of acidity and ionic sinks on animal bone char dissolution | Research | International | | READING |
| 2009 | Flyer: New Natural Phosphorus Fertilizer | Fertiliser market and growers | International | | READING |

Presentation details:
The presentations at Rothamsted Research (the largest agricultural research centre in the UK) and Forest Research (a world leader in the research and development of sustainable forestry and the UK's leading organisation for forestry and tree related research) were by invitation.

Publication details:
Warren, G.P., Robinson, J.S. and Someus, E. 2009. Dissolution of Phosphorus from Animal Bone Char in 12 Soils. Nutrient Cycling in Agro-ecosystems (accepted).

1. Preparation and submission of Partner 3's first scientific publication from the Project (Dissolution of Phosphorus from Animal Bone Char in 12 Soils) to an internationally recognised journal (Nutrient Cycling in Agroecosystems). The paper provides a detailed account of research conducted in Task 4.1, and has since been accepted following minor corrections.

1. Drafting of material for a second journal paper on the relationship between the extractability and speciation of soil organic C and P; the data are obtained from Tasks 4.1 (Reading) and 4.2 (Rostock, UoR) and will provide a unique integration of physico-chemical (hot water extraction) and spectroscopic (pyrolysis-field ionisation mass spectrometry) techniques for elucidating the coupling of C and P forms in soils amended with the Protector.

2. A third paper is currently under internal review at Reading, on the effects of acidity and ionic sinks on animal bone char dissolution; this research was conducted under Task 4.1, and will also be published in an international journal.

## P4 UOR

Exploitable knowledge and its use

| **Exploitable Knowledge** (description) | **Exploitable product(s) or measure(s)** | **Sector(s)** of application | Timetable for commercial use | Patents or other IPR protection | **Owner** & Other Partner(s) involved |
|---|---|---|---|---|---|
| Biofertiliser effects of ABC fermented with Trichoderma | An ABC compatible Trichoderma harzianum strain | 1. Fertiliser<br>2. Biocontrol | | | **Partner 4 UoR** & all project partners involved |

Overview table on dissemination of knowledge

| **Planned/actual Dates** | **Type** | **Type of audience** | **Countries addressed** | **Size of audience** | **Partner responsible /involved** |
|---|---|---|---|---|---|
| 2008 | Publication: Kruse et al. (2008) proceeding book contribution (Canada) and web-presentation | Research, Higher education | World-wide | | UOR, TERRA |
| 28.-29-02- 2008 | Poster and web-presentation, Osnabrück, Germany | Research, Higher education | Germany | 100 | UOR, TERRA |
| 10.- 11-11-2008 | Conference presentation, Oral and web presentation, Braunschweig, Germany | Research, Higher education, Industry (sector: Fertilizer production), politicians | Germany | 100 | UOR |

Online availability:
www.dbges.de/wb/media/bdbg/Baum_et_al_Osnabrueck_2008_new.pdf
http://www.lightsource.ca/brochures/pdf/activity_report_2007/37_Leinweber.pdf

UoR published the following results of research within Protector:

- Baum, C., Leinweber, P., Eckhardt, K.-U., Someus, E., Halasz, M. (2008): Auswirkungen der Applikation von mit *Trichoderma harzianum* inokulierter Knochenkohle auf die mikrobielle Biomasse, Enzymaktivitäten und die Zusammensetzung der organischen Substanz des Bodens. Tagung der Kommission III der DBG, „Bodenbilogische Indikatoren für eine nachhaltige Bodennutzung“ Osnabrück. (in German, published online:

(www.dbges.de/wb/media/bdbg/Baum_et_al_Osnabrueck_2008_new.pdf)

- Kruse, J.; Leinweber, P.; Baum, C.; Godlinski, F.; Someus, E.: Speciation and Quantification of Inorganic and Organic Phosphorus Forms in Environmental Samples by P L-edge XANES.. In: Canadian Light Source ; Dalzell, M. (eds.): Canadian Light Source, Inc. Activity Report 2007. Saskatoon, Canada, 2008. - ISBN 978-0-9783761-1-6, pp. 89 - 90.

Poster presentation:
„Effects of animal bone charcoal with *Trichoderma harzianum* on microbial biomass, enzyme activities and the composition of organic matter in the soil“ poster presentation at the conference of the German Society of Soil Science in Osnabrück, 28.-29.2.2008

In November 2009 a Symposium “Resource-protecting application of phosphorus in agriculture” (in German) was held at the Julius-Kühn-Institute für Pflanzenbau und Bodenkunde, Braunschweig

(Formerly Federal Research Station - FAL). P. Leinweber gave an oral presentation ("Options for agricultural use of P from bone char: results of the EU-project PROTECTOR")

## PARTNER 5 - LUH

Integration of PROTECTOR into teaching: The Institute of Plant Pathology and Plant Protection is integrating the knowledge about the possibilities of ABC use in practical plant production and biological control of soil-borne plant diseases into teaching in Bsc. and Msc. courses for students of Plant Biotechnology and Horticultural Science.

Conference presentation:
(1) The Institute of Plant Protection and Plant Diseases, Leibnitz University Hannover (P5; LUH), in October 2007 organized a 3-day joint meeting of all 4 working groups of COST Action 870. COST = "European Co-operation in the field of Scientific and Technical Research". COST Action 870 = "From production to application of arbuscular mycorrhizal fungi in agricultural systems: a multidisciplinary approach".
The expected number of participants were coming from European countries.P5 (LUH) besides other results, presented outcomes of his work within the PROTECTOR project during this meeting.

The main objective of the COST action 870 Action was to take a multidisciplinary approach to increase the knowledge needed for implementation of arbuscular mycorrhizal fungi in agricultural systems, in order to reduce agricultural inputs and reduce losses to the environment.
In previous COST Actions (821, 838), considerable amounts of knowledge and insights on AM fungi have been developed. This COST Action focuses on the use of this obtained knowledge in practical systems.
The COST Action is novel in that it takes a multidisciplinary approach by bringing together diverse scientific areas ranging from applied mycorrhizal research, plant breeding and (low input) arable farming. The synergism that will occur by combining the scientific areas of plant breeding and mycorrhizal research is of particular importance. Plant breeding programmes have resulted in crops that have higher levels of resistance to pathogens, but they seem to show a reduced responsiveness and colonisation of AM fungi. More research on plant breeding is desirable to detect the plant genes involved in mycorrhization with the objective of developing crops with enhanced responsiveness and colonisation of AM fungi, leading to enhanced use of mycorrhizal resources in agriculture, and thereby increasing the sustainability of agriculture.

(2) LUH presented research results from the PROTECTOR project during the 9th International Congress of Plant Pathology (ICPP; Turin, August 2008).

Abstract of the LUH contribution to the 9th ICPP:

Effect of arbuscular mycorrhiza and bone charcoal on Fusarium disease of tomato
*H. von Alten*
*Institute of Plant Pathology and Plant Diseases, Herrenhaeuser Str. 2, D-30419 Hannover, Germany*
*Email: von-alten@ipp.uni-hannover.de*
Only a limited percentage of livestock biomass can be consumed by humans directly. In the EU during slaughtering and food processing from cattle alone, about 1 million tons/year bone by-products have to be handled. Bone meal can be turned into animal bone charcoal (ABC) using high temperatures and exclusion of oxygen. This sterile material contains high amounts of calcium and phosphorus and only low amounts of heavy metals; however, the phosphorus is not easily available to plant roots. This makes ABC interesting as a P-fertilizer for organic vegetable production. In greenhouse experiments with mycorrhizal

and non-mycorrhizal tomato plants in quartz-sand or a quartz-sand/peat mix, growth and P-uptake was measured, with ABC as the only P-source. *Fusarium oxysporum* f. sp. *radicis lycopersici* was inoculated as a soil-borne pathogen. The severity of the fusarium disease depended on the type of P-source used and the presence of the mycorrhizal symbiont.

(3) Results of the LUH activity within PROTECTOR regarding biocompatibility of AMF-isolates and biocontrol organisms will be presented with a **poster** during the 6th ICOM (International Conference On Mycorrhiza) in Belo Horizonte, Brazil August 9th to 14th, 2009. The ICOM is in general by far the most important international Conference regarding mycorrhizal research worldwide, it can be expected that the number of participants will be about 1000.

Overview table on dissemination of knowledge

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner |
|---|---|---|---|---|---|
| August 2008 | Conference 9th Intenational Congress of Plant Pathology (ICPP; Turin, August 2008). Effect of arbuscular mycorrhiza and bone charcoal on Fusarium disease of tomato | Research | World | 200 | LUH |
| August 2009 | Conference | Research | World | app. 800 | LUH |
| 2009 | Conference | Research | Europe | app. 60 | LUH |
| 2009 | Publication | Research | World | unknown | LUH |

## PARTNER 6 -UFZ

Overview table on dissemination of knowledge:

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 12-10-2006 | Oral presentation Colloquium (Universities of Freiberg and Chemnitz) | Research | Germany | ~50 | UFZ |
| 23-05-2007 | Oral presentation Conference- Soc. of Env. Tox. & Chem.-EU (SETAC-EU),Porto | Research | EU | ~150 | UFZ |
| 16-05-2007 | Oral presentation Colloquium at the UFZ | Research | Germany | ~120 | UFZ |

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 12-09-2007 | Oral presentation at SETAC-GLB, German Language Branch | Research | Germany | ~80 | UFZ |
| 23-05-2007 | Poster at SETAC-EU, Porto | Research | EU and Germany | ~1000 | UFZ |
| 12-09-2007 | Poster at SETAC-GLB, German Language Branch (Leipzig) | Research | Germany, Austria, Switzerland, The Netherlands | ~400 | UFZ |
| September 2007 | Publication "Proteomics" | Research | international | | UFZ |
| February 2008 | Publication "ET&C" | Research | international | | UFZ |
| 25-05-2008 | Oral presentation SETAC-EU, Warsaw | Research | EU | ~200 | UFZ |
| 26-05-2008 | Poster at SETAC-EU, Warsaw | | | | |
| 24-09-2008 | Oral presentation at SETAC-GLB, German Language Branch (Frankfurt) | Research | Germany, Austria, Switzerland, The Netherlands | ~45 | UFZ |
| 14.11.2008 | Oral presentation at INRA, Paris | Researchers, Industry | France | 35 | UFZ |

Short description: SETAC-EU and -GLB conferences are the major european and german speaking conferences in Europe with a strong focus on ecotoxicological and environmental contamination topics. They are meeting points for the main part of the ecotoxicologists from industry, universities, research institutes and regulatory authorities from the different EU members, but are also very much visited by overseas researchers (US, Japan, Hongkong, Australia). The topics range from chemical, biological, toxicological and ecotoxicological risk and hazard assessment to discussions and seminars about regulatory topics (REACH, new emerging substances etc. http://www.setaceumeeting.org/ , http://www.setac-glb.de/266.html?&L=0 )

**Details about the publications which were financed by and done for the PROTECTOR project:**

1. Gündel U, Benndorf D, von Bergen M, Altenburger R and Küster E. 2007. "Vitellogenin cleavage products as indicators for toxic stress in zebra fish embryos: a proteomic approach" Proteomics 7: 4541-4554
2. Schreiber R, Altenburger R, Paschke A and Küster E. 2008. "How to deal with lipophilic and volatile organic substances in microtiter plate assays?" Environmental Toxicology and Chemistry 27 (8), available online

**Details about the publications which will be submitted in the near future:**

- A publication was submitted in 2008 which was done to evaluate the possible uptake of PAH (possible contaminants of ABC material) into zebrafish embryos. This publication will be important for the international ongoing discussion to increase the impact of the zebrafish embryo assay as an

animal replacement test in the risk and toxicity assessment of chemicals (also in view of the REACH regulation)

- A publication is going to be submitted in 2009 in which the development of a new genotoxicity assay for the risk assessment of environmental samples will be presented and which was developed for the toxicity assessment of ABC material.

Scientific dissemination was continued by an oral presentation at the European meeting of the Society of Environmental Toxicology and Chemistry (SETAC-EU) in Warsaw in the year 2008 by the PhD student Ulrike Gündel. Two other presentation are accepted as poster presentation about a new assay developed for the analysis of sublethal effects to zebrafish embryos and the possibility to calculate a hazard of bioconcentration of PAHs to fish by using fish embryos instead.

Both results presented in the poster presentations include experiments leading to the toxicity assessment of ABC/PROTECTOR leachates to different aquatic organisms under sub-chronic exposure conditions. One manuscript was published in the journal Proteomics (Gündel et al. 2007, Proteomics 7: 4541-4554) using the results of the research from Protector about new ways of sublethal toxicity evaluation with zebra fish embryos. Another manuscript was accepted in the journal "Environmental Toxicology and Chemistry" (Schreiber et al. ETC, accepted). The results in this manuscript are helpful for a meaningful analysis of lipophilic substances in aquatic bioassays and are important for the PROTECTOR project as lipophilic substances were observed in certain lots of the ABC material and as these lipophilic components might be concentrated in the soil when the ABC material is used as a fertilizer and so might pose a long term risk to soil ecosystems.

## PARTNER 7 -UNITO

Overview table on dissemination of knowledge

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| February 11th 2006 | Exhibition Innovagro, Udine fair | General public, hi-tech companies, SMES, R&D centres dealing with biotechnologies applied to agro-food, health and environment, universities, professionals | Italy and Eastern Europe | ~ 1000 | UNITO |
| May 14th -18th 2006 | Conference IOBC/WPRS WORKING GROUP Meeting Integrated Pest Control in Protected Crops, Mediterranean Climate, Spain. | Higher education, research | EU | ~ 300 | UNITO |
| August 13th-17th | Conference: | Higher education, | EU | ~ 300 | UNITO |

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 2006 | Poster presented at 8th Conference of the European Foundation for Plant Pathology & British Society of Plant Pathology Presidential Meeting 2006, Copenhagen | research | | | |
| November 2007 | Publication: Informatore Fitopatologico – La Difesa delle Piante, 57 (11), 44. | General public, higher education, research, farmers | Italy | ~ 2000 | UNITO |
| August 23rd – 30th 2008 | Poster presented at Conference: ICPP2008, 9th International Congress on Plant Pathology | General public, higher education, research. | 84 countries worldwide | ~ 2000 | UNITO |
| August 2008 | Publication: Pugliese M., Liu J., Gilardi G., Someus E., Gullino M.L., Garibaldi A. (2008) – Improving suppressiveness towards Phytophthora nicotianae using bone charcoal. Journal of Plant Pathology, 90, S2.272 | General public, higher education, research. | International | ~ 5000<br><br>(IP = 0.974) | UNITO |
| Planned on March 5th 2009 | Poster at Congress: Incontri Fitoiatrici 2009, Torino, Italy | General public, higher education, research, farmers | Italy | ~ 300 | UNITO |

Innovagro is an international event hold in Udine Fair (Italy) to support the participation to European research programmes of SMEs and R&D centres active in the field of biotechnology based diagnostic and detection systems and applications for the Food, Health and Environmental sectors (www.congresses.net/innovaction/innovagro/default.asp; short description of Protector: www.congresses.net/innovaction/project_details.asp?IDProject=111).

IOBC/WPRS WORKING GROUP is one of six Regional Sections of the International Organisation for Biological Control. IOBC was established in 1955 to promote environmentally safe methods of pest and disease control in plant protection. Members of WPRS are individual scientists, governmental, scientific or commercial organisations from 24 countries of Europe, Mediterranean region and the Middle East. An abstract was published at the meeting in Murcia (Spain), May 14-18, 2006 (http://www.iobc-wprs.org/pub/bulletins/bulletin_2006_29_04_abstracts.pdf).

8th Conference of the European Foundation for Plant Pathology & British Society of Plant Pathology Presidential Meeting 2006 was held in Copenhagen (Denmark) on August 13-17 2006. Data have been presented a poster and the abstract of the poster is available at http://www.efpp06.kvl.dk.

A project description, including project objectives and expected results, has been published on "Informatore Fitopatologico – La Difesa delle Piante", an Italian journal about phytopathology and crop protection, edited by "Il Sole 24 Ore, Edagricole".

ICPP2008 was held in Turin, Italy, in August 2008. Is the most important international congress on Plant Pathology (www.icpp2008.org). A poster on protector has been presented and an abstract published on the proceedings of the congress (Journal of Plant Pathology, 90, S2).

"Incontri Fitoiatrici" is an annual Italian meeting on pests and diseases management hold in Torino, Italy. A poster will be presented there in 2009 as future planned activity for dissemination of knowledge.

## PARTNER 9 -MIGAL

To-and-through educational organizations as network centres for dissemination of the project findings to other educational organizations: 1 workshop was planned in MIGAL, supported with regional electronic media.
One big conference is planned for the end of 2008 with local Agro industry and retailers with combined technical-economical highlights to be held specifically targeting agro-industrial dissemination development. One big presentation is planned in an international trade fair that will take place in Tel Aviv called AGRITECH (www.agritech.org.il). 500 units CD disseminated for selected farmers in Northern and Southern Israel will be distributed.

| Planned/actual Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| October 2007 | Media briefing | Higher education | Israel | 12 | MIGAL |
| January 2008 | Conference | Research | Israel | 300 | MIGAL |
| 08-07-2008 | Exhibition | Farmers | Israel | 3,000 | MIGAL |
| Spring/summer/2008 | Jordan Valley Regional seminar (general issue of decreasing the use of chemicals in modern agriculture | Farmers | Israel Regional Municipality hall | | MIGAL |
| Spring/summer/2008 | Upper Galillee Regional seminar (general issue of decreasing the use of chemicals in modern agriculture | Farmers | Israel Gadash farm hall | | MIGAL |
| Spring/summer/2008 | Western Galilee | Farmers | Israel Regional Municipality hall | | MIGAL |

P11 SONAC

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 2008 | Food industrial animal by-product processing workshop | Industrial partners | NL, UK, DE, | 50 | SONAC |

P12 ARPAD

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 2008 | OPEN DAYS | Agriculture farmers | HU | 50 | ARPAD |

**Table 2: PROTECTOR Overview summary table on dissemination plan of knowledge**

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| WEB AND ELECTRONIC COMMUNICATION | | | | | |
| 2005 | Project general web-site with 6 languages abstract | All | International | 10000's | TERRA<br>ALL |
| 2006 | Website abstract | all | Dutch language | 10000's | PRI |
| 2006- 2007 | EXPANDED WEB + electronic communication | CONSUMERSRETAILERS, CORDIS, AUTHORITIES | International focus on EU + USA | 10000's | TERRA<br>ALL |
| 2005-2008 | FAQ/NEWSLETTER e-mail highlighted message | all | interactional | 10000's | TERRA |
| SCIENTIFIC PUBLICATION | | | | | |
| September 2007 | Publication "Proteomics" | Research | international | | UFZ |
| February 2008 | Publication "ET&C" | Research | international | | UFZ |
| November 2007 | Publication: Informatore Fitopatologico – La Difesa delle Piante, 57 (11), 44. | General public, higher education, research, farmers | Italy | ~ 2000 | UNITO |
| August 2008 | Publication: Pugliese M., Liu J., Gilardi G., Someus E., Gullino M.L., Garibaldi A. (2008) – Improving suppressiveness towards Phytophthora nicotianae using bone charcoal. Journal of Plant Pathology, 90, S2.272 | General public, higher education, research. | International | ~ 5000<br>(IP = 0.974) | UNITO |
| Beginning 2009 | Publication on the selection of microbes (peer reviewed English journal) | Research & Industry | World-wide | | PRI |
| Beginning 2009 | publication on biolo-gical control of plant diseases using ABC | Research & Industry | World-wide | | PRI |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | with the selected bacteria (peer reviewed English journal) | | | | |
| Nov 2008 | Peer-reviewed paper accepted for publication in Nutrient Cycling in Agro-ecosystems (Dissolution of Phosphorus from Animal Bone Char in 12 Soils) | Research | International | | READING |
| 2009 | Peer-reviewed paper on the relationship between the extractability and speciation of soil organic C and P | Research | International | | READING and ROSTOCK (UoR) |
| 2009 | Peer-reviewed paper on the effects of acidity and ionic sinks on animal bone char dissolution | Research | International | | READING |
| 2008 | Publication: Kruse et al. (2008) proceeding book contribution (Canada) and web-presentation | Research, Higher education | World-wide | | UOR, TERRA |
| 2009 | Book publication: E. Someus, Food crop mineral deficiency and disturbance stress mitigation in temperate climatic regions by economical and environmental valorization of agricultural by-products Nova Science, New York, 2009. | Research, Industry, General public | World-wide | | TERRA |
| 2009 | E. Someus, Recycling and upgrading of bone meal for environmentally friendly crop production and nutrition: the PROTECTOR project, Handbook of waste management and co product recovery, Chapter 23., Woodhead publishing | Research, Industry, General public | World-wide | | TERRA |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| POSTER PRESENTATION | | | | | |
| 22-5-2008 | Joeke Postma, Els Nijhuis, Francesca Clematis, and Edward Someus, 2008. Een nieuwe carrier voor biologische bestrijders. Gewasbeschermingsmanifestatie, 22 May, Ede, NL | Research | NL | 150 | PRI |
| 28.-29.02. 2008 | Poster and web-presentation, Osnabrück, Germany | Research, Higher education | Germany | 100 | UOR, TERRA |
| FLYER | | | | | |
| 22-5-2008 | Flyer | Research & Companies (Agriculture) | NL | 100 | PRI |
| 2009 | Flyer: New Natural Phosphorus Fertilizer | Fertiliser market and growers | International | | READING |
| | | | | | |
| NATIONAL/INTERNATIONAL CONFERENCE AND SYMPOSIUM | | | | | |
| May 14th -18th 2006 | Conference IOBC/WPRS WORKING GROUP Meeting Integrated Pest Control in Protected Crops, Mediterranean Climate, Spain. | Higher education, research | EU | ~ 300 | UNITO |
| 23-05-2007 | Oral presentation Conference- Soc. of Env. Tox. & Chem.-EU (SETAC-EU),Porto | Research | EU | ~150 | UFZ |
| August 13th-17th 2006 | Conference: Poster presented at 8th Conference of the European Foundation for Plant Pathology & British Society of Plant Pathology Presidential Meeting 2006, Copenhagen | Higher education, research | EU | ~ 300 | UNITO |
| 23-05-2007 | Poster presentation at SETAC- EU, Porto | Research | EU and Germany | ~1000 | UFZ |
| October 2007 | COST Action 870 joint meeting | Research | World | 100 | LUH |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | opral presentattion | | | | |
| 12-09-2007 | Oral presentation at SETAC-GLB Conference, German Language Branch | Research | Germany | ~80 | UFZ |
| 12-09-2007 | Poster presentation at SETAC-GLB, German Language Branch (Leipzig) | Research | Germany, Austria, Switzerland, The Netherlands | ~400 | UFZ |
| January 14th -15th , 2008 | International conference presentation: FEED – SEG, January 14-15, 2008,Mosonmagyaovar, Hungary, http://www.matchmaking.at/feedseg/ | Research | World | 200 | TERRA |
| January 2008 | Conference | Research | Israel | 300 | MIGAL |
| 22-5-2008 | Publication of Abstract Dutch Crop Protection | Research & Higher education & Companies (Agriculture) | NL | 600 | PRI |
| 25-05-2008 | Oral presentation SETAC-EU, Warsaw | Research | EU | ~200 | UFZ |
| 26-05-2008 | Poster at SETAC-EU,Warsaw | | | | |
| 14-10-2008 | Oral presentation International symposium ORBIT | Research & Industry (organic residues) | World-wide | 300 | PRI |
| August 23rd – 30th 2008 | Poster presented at Conference: ICPP2008, 9th International Congress on Plant Pathology | General public, higher education, research. | 84 countries worldwide | ~ 2000 | UNITO |
| September 8th - 10th, 2008 | International conference presentation: BIOCHAR, September 8-10, 2008, Newcastle-Gateshead, UK, Poster peresentation | Research | World-wide | 500 | TERRA |
| 24-09-2008 | Oral presentation at SETAC-GLB, German Language Branch (Frankfurt) | Research | Germany, Austria, Switzerland, The Netherlands | ~45 | UFZ |
| 14-10-2008 | Publication of Abstract (book + CD) | Research & Industry (organic residues) | World-wide | 300 | PRI |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | ORBIT www.orbit2008.de | | | | |
| 11-11-2008 | Conference presentation, Oral and web presentation, Braunschweig, Germany | Research, Higher education, Industry (sector: Fertilizer production), politicians | Germany | 100 | UOR |
| August 2009 | Conference – poster presentation during the 6th ICOM (International Conference On Mycorrhiza) The ICOM is in general by far the most important international regarding mycorrhizal research worldwide. | Research | World | app. 800 | LUH |
| 2009 | Conference- oral and posrter presentation. COST action 870 | Research | Europe | app. 60 | LUH |
| Planned on March 5th 2009 | Poster at Congress: Incontri Fitoiatrici 2009, Torino, Italy | General public, higher education, research, farmers | Italy | ~ 300 | UNITO |
| 2009 | Publication | Research | World | unknown | LUH |
| SEMINAR AND WORKSHOP | | | | | |
| 07-02-2007 | Oral presentation at Rothamsted Research Institute, Seminar | Research | UK | ~50 | READING |
| 07-05-2008 | Oral presentation at Forest Research Institute, Seminar | Research | UK | ~20 | READING |
| 14-11-2008 | Oral presentation at INRA, Paris | Researchers, Industry | France | 35 | UFZ |
| Spring/summer/2008 | Jordan Valley Regional seminar (general issue of decreasing the use of chemicals in modern agriculture "Model farms in Farmer's fields" "OPEN DAYS" | Farmers<br><br>Public information and training of consumers and retailers to promorte acceptance of the product. | Israel Regional Municipality hall | | MIGAL |
| Spring/summer/2008 | Upper Galillee Regional seminar (general issue of decreasing the use of chemicals in modern agriculture "Model farms in | Farmers<br><br>Public information and training of consumers and retailers to promorte acceptance of the | Israel Gadash farm hall | | MIGAL |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | Farmer's fields" "OPEN DAYS" | product. | | | |
| Spring/summer/2008 | Western Galilee<br><br>"Model farms in Farmer's fields" "OPEN DAYS" | Farmers<br><br>Public information and training of consumers and retailers to promorte acceptance of the product. | Israel Regional Municipality hall | | MIGAL |
| 2007-2008 | Workshop at each education center. | To-and-through educational organizations. Teachers from from other education organisations. | NL, UK, DE, IT, IL, ES, USA | 1000' | PRI, READING, UOR,, UNITO, UHAN, MIGAL, CSIC |
| 2008 | Food industrial animal by-product processing workshop | Industrial partners | NL, UK, DE, | 50 | SONAC |
| 2008 | Recycling and upgrading of organic waste and by-products from different food chains | Industrial partners | NL, UK, DE, USA | 100 | TERRA |
| 2008 | OPEN DAYS | Agriculture farmers | HU | 50 | ARPAD |
| FAIR AND EXHIBITION | | | | | |
| 11-02-2006 | Exhibition<br>Innovagro, Udine fair | General public, hi-tech companies, SMES, R&D centres dealing with biotechnologies applied to agro-food, health and environment, universities, professionals | Italy and Eastern Europe | ~ 1000 | UNITO |
| 08-07-2008 | Exhibition | Farmers | Israel | 3,000 | MIGAL |
| INTEGRATION INTO TEACHING | | | | | |
| | The Institute of Plant Pathology and Plant Protection is integrating the knowledge about the possibilities of ABC use in practical plant production and biological control of soil-borne plant diseases into teaching in Bsc. and Msc. courses for students of Plant Biotechnology and Horticultural Science. | | | | LUH |
| 12-10-2006 | Oral presentation<br>Colloquium (Universities of Freiberg and Chemnitz) | Research | Germany | ~50 | UFZ |
| 16-05-2007 | Oral presentation<br>Colloquium at the UFZ | Research | Germany | ~120 | UFZ |
| MEDIA BRIEFING | | | | | |

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| | | | | | |
| October 2007 | Media briefing | Higher education | Israel | 12 | MIGAL |
| PRESENTATION TO AUTHORITIES | | | | | |
| 2007 | Presentation to German Authority | Presentation to BVL Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (BVL) (governmental organization for permissions) | Germany | | UOR + ALL |
| 2006-2007-2008 | Continuous Project presentation and authority control and test programme | Hungarian Plant Protection and Soil Conversation Autority belonging to the Ministry of Agriculture | Hungary | | TERRA |
| DISSEMINATION TO AGRO INDUSTRY | | | | | |
| 2007 | BUSINESS PLAN | Agro Industry INVESTORS | Italy, Germany, The Netherlands, USA | 500 | TERRA |
| 2007 | CD | Agro traders/users | EU and USA | 500 | TERRA |
| 2008 | Marketing agreement | Agro Industry INVESTORS | EU and USA | | TERRA |

## Section 3 - Publishable results

Publishable exploitable results:

Result description (product(s) envisaged, functional description, main advantages, innovations)

**The PROTECTOR technology for recycling and upgrading of bone meal for environmentally friendly crop protection and nutrition**

- methods for optimization of solid carrier based soil fungus microbiological substances
- methods for scale up of solid carrier based soil fungus microbiological substances
- methods and apparatus for solid state fermentation technology
- methods and apparatus for solid state formulation technology

P1 is one of the leading companies in the area of international carbonization, solid state fermentation and formulation science and technology; it provides an original source of knowledge and an industrial engineering base. The specific bone char thermal treatment technology developed and designed by P1 is the only one known on the international market which can produce the bio specific bone char solid carrier. The integrated bone char and biotech processing technology is the only one known on the international market with specific performance.

**The production and use of animal bone charcoal for biotechnological solid carrier is a highly innovative carbonization method and product.** The PROTECTOR is the only known technology system, where solid carrier thermal treatment and biotechnological systems are built together. As Animal Bone Charcoal (ABC) carrier development and Solid Substrate Fermentation and Formulation (SSFF) technology innovative developments run in parallel, a coherent link has been structured between the two tasks. Therefore, the production of such innovative solid carrier or carriers requires advanced knowledge, special care and considerations, in depth scientific and technical understanding and tests. **Selection of prime and second best natural soil microbial strains** compatible with Animal Bone Charcoal for (1) mobilization of the phosphorus content of the ABC carrier for plant uptake and (2) positive biocontrol effect. **Innovative Solid Substrate Fermentation and Formulation (SSFF) technology has been developed and optimized**.

During the applied scientific RTD and application oriented optimization, the PROTECTOR products have been successfully multiple tested for several years under different climatic, soil and agro-industrial true value production conditions in Hungary, Israel, Italy, Germany and The Netherlands. The EU relevant permitting field tests have been completed at the end of 2008.The results have clearly indicated the positive PROTECTOR efficiency under different field condition. **The PROTECTOR open ecological field Application Permit has been received in 2009. Permit Number:** 02.5/97/7/2009.

The output PROTECTOR end product provides the following combined effects:

4. Plant growth promotion, for natural substance support to get higher plant yields with better quality and safer products.
5. Biological control effect against soil borne plant pathogens, for substitution or significantly lowering of the input of agro chemicals.
6. Natural fertilization: Food crop mineral deficiency and disturbance stress mitigation in temperate climate regions by restoration of soil natural balance. Substitution of highly energy intensive artificial fertilizers, including substitution of the Cadmium and Uranium heavy metal contaminated phosphate rock fertilizers.

**Possible market applications (sectors, type of use) or how they might be used in further research (including expected timings)**

**Targets:**

- Organic vegetables, herbal and medicinal plant production
- Low input farming
- Farming in ecologically and environmentally sensitive areas
- Integrated farming

**Stage of development: prototype**

**Status of the development:**

Innovative Solid Substrate Fermentation and Formulation technology and "product like" pilot plant has been developed for effective formulation of several types of microbiological substances on soil application specific chars and minerals during the FP6 PROTECTOR project. Scale up optimization and comprehensive industrialized engineering design developed for 30,000 $m^3$/year input feed stream, including biochar specific auxiliary systems for turn key installation as of modern US/EU industrial standards. The EU relevant four years permitting field has been completed.

**Market and economical analysis results show very positive trends for the PROTECTOR.**

**Collaboration sought or offered (manufacturing agreement, financial support or investment, information exchange, training, consultancy, other):** After years of RTD, advanced engineering, validation and field demonstration works the PROTECTOR technology is ready to be licensed and to implement full scale industrial and production systems.

Offered collaboration:

- License agreement
- Marketing agreement
- Manufacturing agreement
- Joint venture agreement

## Collaborator details:

The Terra Humana provides practical applied research and engineering design „ready to commercialize" results which has potential international commercial interest and strategies for how to exploit it. The status of the 3R Carbonization technology is post development, proven and demonstrated with clearly achieved industrial phase.

**PROTECTOR licensing considerations:**

- **Juridical and financially clean and clear, transparent and documented legal status.**
- **Original technology**, which is also including several novel part solutions.
- **Patented solution**, but the key components are still protected by confidential, non public know how and design.
- **Comprehensive technology design, protected by confidential and non public full scale engineering system**, which has been designed in both traditional drawing style and AUTOCAD 3D INVENTOR in very detail, as of manufacturing execution design.
- The PROTECTOR process control, electric and electronic installations are based on the Japanese OMRON software and hardware, which is fully compatible with all major industrial electronic

systems, including Honeywell, Rockwell Automation - Allen Bradley, Siemens, Endress+Hauser and Burr Brown.

- **The PROTECTOR meets all EU and US industrial norms and standards** and also prepared for stricter environmental normative changes beyond 2012.The inventor Edward Someus is providing long termed cooperation and world-wide technical support + skilled know-how service, training and license maintenance for implementation and systematic operations.
- „**Value for Money" by the combination of reasonable License and Royalty Fees.**

Intellectual property rights granted. The Protector technology is an original, patented and intellectually property right protected full scale industrial engineering and design solution.

Contact details

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