REFERTIL

Improvement of comprehensive bio-waste transformation and nutrient recovery treatment processes for production of combined natural products

Compost and Biochar Safety, Economy and EU Law Harmonization Conference

REFERTIL PRESENTATIONS ABSTRACT BOOKLET

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Flemish Government Building

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INTRODUCTION OF THE REFERTIL PROJECT

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Current farming practices rely heavily on external inputs such as mineral fertilisers and chemicals to achieve intensive agricultural production. The EU-funded (REFERTIL) project http://www.refertil.info/ aims to convert local organic biowaste and by-product streams into safe biochar and compost products produced under market competitive and economical conditions. These products are designed to be affordable, environmentally sustainable and in accordance with strong policy and food safety regulations informed by rigorous scientific and technical data from proven field demonstrations.

Progress thus far includes a guarantee of a high-level of protection for human health and the environment for added value recycling of organic waste and agriculture residues, including the organic Phosphorus recovery case in economical industrial scale. This was achieved by meeting stringent requirements on the quality criteria and detailed analyses for compost and biochar feed material sustainability; advanced technology developments towards zero emission production ensuring output product safety, efficiency and market competitiveness. All REFERTIL developed biochar are high grade, fully quality controlled and fully safe products under any climatic and soil conditions.

Beyond the key enabling technological/product development, the REFERTIL applied science researchers and industrial engineers together developed an extensive regulation policy to accompany the biochar and compost, which aims to increase the confidence of farmers using it for food and feed production. In this context improved compost/biochar quality and safety criteria and standards developed and determined. Full industrial scale ABC Phosphorus recovery and recycling plant with market competitive industrial manufacturing installation is prepared. They also provided market viability information and scientific data for setting up organic by-product and biowaste recycling targets, which supports policymakers in revising EU fertiliser regulations.

The results of the REFERTIL project have the potential to reduce by 20% at EU scale the import of Phosphate mineral fertilizers and avoid producing 10 million tonnes of carbon dioxide-equivalent emissions in Europe. By providing a safe and affordable alternative, this contributes to reducing the EU's carbon footprint, the use of imported mineral fertiliser and chemicals, while improving food safety, supply security and expanding bio-based EU economy, particularly in the horticultural SME farming sector.

BIOCHAR PROCESSING TECHNOLOGY IMPROVEMENTS TOWARDS ECONOMICAL INDUSTRIAL SCALE

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Biochar is plant and/or animal biomass by-product based stabile carboniferous substance with well defined and controlled quality that is processed under reductive thermal conditions. Biochar is a specific carbonized product of specific pyrolysis process with designed quality, environmental and ecological safety, performance and character for food crop production applications.

Animal Bone bioChar (ABC) having low carbon content and as high as 30% P_2O_5 nutrient composition with sequenced release P-fertilization effect. ABC is highly macroporous, formulation optimized for significant enhancing of soil microbiological life, having high water holding and macromolecular organic nutrient retention. The fully safe ABC is used at low doses (200–600 kg/ha) and in cases when justified even up to 1,000 kg/ha.

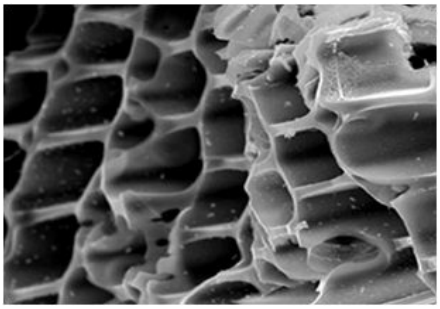
Plant based biochar (PBC) is high stabile carbon content plant origin micro- and meso porous carboniferous soil improver products, with relatively high water holding, nutrient retention and C-sequestration capacity, but almost no soil fertilization effects with economical value.

To obtain a high quality biochar product, mainly two aspects have to be considered: the input feed material and the performance of the pyrolysis technology design that provides the treatment efficiency. Sustainable biomass feed by-products and residues for biochar production may not compete with human food, animal feed, plant nutrition supply; and land use for human and animal food production. Beside the input material characteristics; the engineering design performance of the pyrolysis technology (heat and mass transfer efficiency in the equipment); the treatment conditions (material core temperature, residence time and pressure conditions) and auxiliary systems are critically affecting the characteristics, quality and safety of the final products, also the process environmental performance. **The developed new generation 3R Pyrolysis is a zero emission thermo-chemical decomposition process of plant and/or animal origin organic waste and by-products in the absence of oxygen, under vacuum and between material core temperature ranges from 450 °C up to 850 °C.**

3R Zero emission technology

Category 3 bone grist and ABC

The macroporous ABC structure



BIOCHAR QUALITY & SAFETY – ACCREDITED BIOCHAR ANALYSIS

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As the accredited laboratory partner of REFERTIL project hundreds of samples from 11 countries have been investigated by WESSLING Hungary in a wide range of materials (e.g. biochar, soil, compost, input waste materials, plant parts).

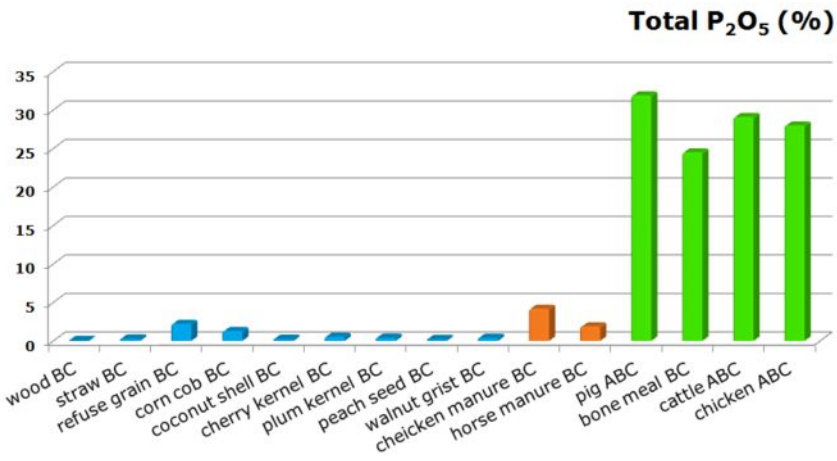
With this high number of tests the quality of the input materials and the output products were characterised. Measurements were directed on one hand to examine useful plant nutrients, phosphorous/carbon/nitrogen content and on other hand to the detection of potential risk factors (PAHs, potential toxic elements, PCBs and dioxins).

In spite of their similar appearance, the microstructure and chemical properties of plant based biochars (PBC) and animal bone biochars (ABC) are quite different, but they can be analysed using the same laboratory methods.

During pyrolysis and other thermal treatment processes PAHs are the main indicator contaminants, its limit value has been defined under 6 mg/kg for biochars. With various biochar processing conditions it has been verified that the technology influences the quality of the product. Between appropriate treatment conditions high quality biochar were made with low PAH content (<1 mg/kg).

PCBs were not detected from biochars, but high chlorine content of the input material was also not expected. As dioxins were never shown too, we have concluded that PCB presence is a good indicator of these persistent and bioaccumulative chemicals.

After the development of the methods for biochar examination in 2014 we have successfully gone through the accreditation process for biochar quality testing as the first and only laboratory in Europe.



Total Phosphorus content of different biochars

SUMMARY OF THE REFERTIL POLICY SUPPORT WORK

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When biochar is irrevocable applied to open and complex soil ecological system, there is also a direct interlink to subsurface water systems, therefore only qualified and safe biochar must be applied. The aim is to ensure that the proposed biochar quality and safety criteria are fully consistent with EU-wide Directives and Regulations for long term.

Fertiliser regulation (EC No. 2003/2003) is only regulating the mineral fertilizers and in current form is not applicable for biochar products. One of the key objective of the REFERTIL project is providing a strong policy support for the EU Commission in revision of the Fertiliser Regulation (Reg. EC No. 2003/2003) and possible inclusion of biochar - as safe organic fertiliser and soil additive. Voluntary biochar certificates having no legal effects.

Biochar parameters	ORGANIC P-FERTILISER	SOIL IMPROVER
Potential toxic elements (mg/kg)		
As	10	10
Cd	1.5	1.5
Cr	100	100
Cu	200	200
Pb	120	120
Hg	1	1
Ni	50	50
Zn	600	600
Organic pollutants		
PAH 16	6	6
PCB 7	0.2	0.2
PCDD/F (ng/kg I-TEQ)	20	20
Particle size distribution	ABC: 1-5mm, 90%	PBC: 1-20 mm, 90%
Bulk density	declaration	declaration
Dry matter content	>80%	>60%
pH	6 - 10	6 - 10
Total Organic C	declaration	20%
N and K total	declaration	declaration
Total P (P_2O_5)	>25%	declaration
Total Ca, Mg	declaration	declaration
Germination inhibition assay	No inhibition	No inhibition
Phytotoxicity	No phytotoxicity	No phytotoxicity
Agronomic efficiency	Should be proved	Should be proved

REFERTIL recommended biochar quality and safety parameters

The REFERTIL consortium integrateded the biochar applied scientific research, industrial engineering, legal and economical aspects. All the knowledge and experience generated during the REFERTIL project time has been united.

The respective EU directives, regulations and also the relevant MS national legislations have been reviewed. Moreover **the economical sustainability of the biochar under market based commercial conditions has been evaluated.** Harmonized and standardized analytical measurements have been developed for determination of the physic-chemical properties, potentially toxic element content and organic pollutants in the biochar materials. A proposed biochar quality and safety criterion system has also been set up which is maximizing the Potential Toxic Element and Organic Pollutant content for safe application. Several workshop meetings have been organized with the EU Commission representatives for joint considerations and also wide range of European biochar science and technology groups have been consulted for knowledge and experience exchange. A detailed policy support report has been submitted to the European Commission.

USE OF COMPOST AND BIOCHAR IN AGRICULTURE: EXPERIENCES FROM THE REFERTIL PROJECT

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The agricultural sector is encouraged to innovate and change strategies for crop nutrition and protection, with the need to revisit the methods of management to satisfy the requirement of environmental sustainability, by the adoption of integrated systems. **The use of compost and biochar has been evaluated** by Agroinnova – University of Torino within the Refertil project, **with the aim to provide farmers more information about their efficacy.** Some examples of the experiences carried out in Italy are reported. Potting trials in greenhouse have been carried out on vegetable crops to evaluate the use compost and biochar as soil improvers, organic fertilizers or growing media.

REFERTIL potting trials in Italy

Suppressiveness trials in greenhouse have been carried out to evaluate the capacity of compost and biochar to reduce plant diseases and field trials on tomato, pepper and lettuce, to validate the use of compost and biochar in farms located in Italy. Composts deriving from animal manure and municipal biowaste reduced seeds germination and plant growth when used as growing media, and consequently they are not recommended to be applied at dosages higher than 15-20% v/v. However they have a good fertilization effect when applied to soil, and increased yields when applied at 10-30 t/ha. Green waste composts are more suitable to be used as growing media, and 50% of them suppressed soil-borne plant pathogens. Animal bone char showed a good fertilization effect on crops, while plant based biochar had few effects on yields and results vary according to soil type. **Different strategies are critically discussed, and new trends for the use of compost and biochar are suggested.**

REFERTIL Greenhouse trials in Italy

Sweet pepper produced in a farm using biochar

REFERTIL Strawberry field trials in Slovenia

BIOCHAR EFFECTS ON POTENTIAL NITRIFICATION AND ECOTOXICITY OF ORGANIC XENOBIOTICS AGRICULTURAL SOIL

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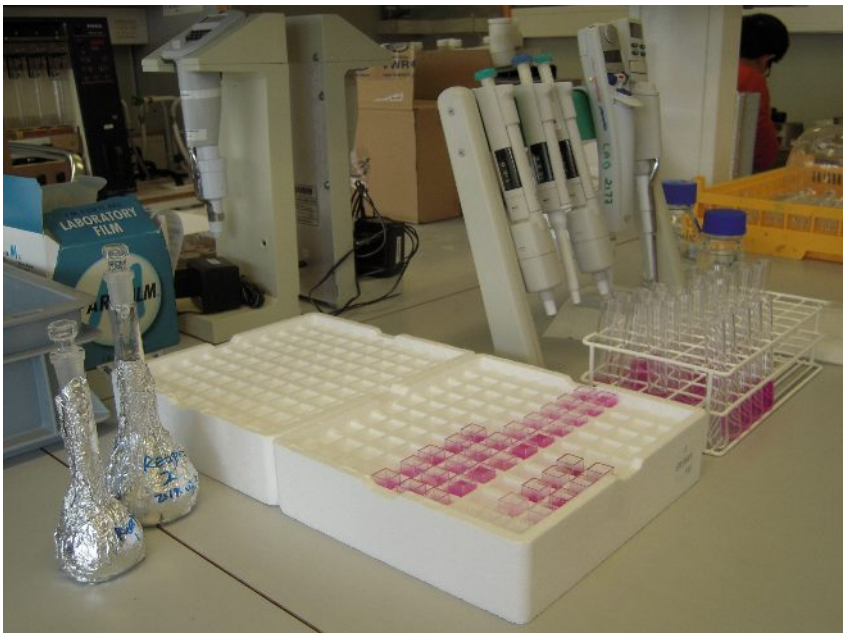
Biochar is a recalcitrant and persistent char product synthesized by pyrolysis of plant- or animal-based biomass and intended for soil amendment. Suggested ecosystem services of biochar include increased soil fertility, carbon sequestration and decreased nutrient leaching. Further, large specific surface area of biochars has the potential to decrease bioavailability of toxic organic contaminants in the soils, through sorptive processes.

Still, however, t**oxic compounds present in the feedstock (heavy metals) or generated during pyrolysis (e.g., polycyclic aromatic hydrocarbons, PAH) necessitates evaluation before wider environmental application of biochar.** The aim of this study was to test the ecotoxicity of biochars in agricultural soil towards potential nitrification as a microbial bioindicator and to test for potential mitigation of the ecotoxicity of widespread organic xenobiotics (linear alkylbenzenesulphonates, LAS) in the presence of biochar.We conclude that the biochars increased soil pH to varying degree, but did not cause severe inhibition of potential nitrification. Thus, based on comparison of ecologically relevant doses and effects on the tested microbial bioindicator, the current biochars had an ecologically acceptable profile. However, no clear effect of LAS sorption to biochar was observed, which could potentially have mitigated LAS ecotoxicity in the soil.



Colorimetric microbial assays

Use of plant based biochar from the farmer's point of view

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A success parameter of recycling of organic wastes in agriculture is that there is a demand of the products to be used in the plant production. **From the farmers' point of view, the products therefore must contain high value nutrients and/or other soil improvement substances and effects.**

Plant based biochars in general have a high content of carbon and a low content of nutrients. For example, wood based biochar used in the Refertil project, contains 80.2% carbon, but only 0.24% N, 0.02% P and 0,12% K. Biochar from straw used in the project contains 78.0% carbon and 0.65% N, 0.5% P and 0.4% K

Field trials with plant based biochar in Denmark

The nutrient values are therefore very low, even at high application rates. The value of the biochar comes from the carbon enrichment; the increased water holding capacity, the cation exchange capacity and high pH-value at acid soils. The yield values of these parameters are very depended on the soil type, climate and crop, and in Denmark it's very difficult to show significant effects because the Danish soils in general are very fertile. The results of 3 years Refertil trials in agricultural crops show no yield effect of plant based biochars at different soil types and with different application rates of 0 to 20 tons of carbon per hectare. The price of biochars is very variable and the needed yield effects depends on the investment assumptions, but most biochars are not relevant to Danish soils at the actual price level.

To increase the soil content of carbon, the farmer can incorporate plant residues (straw or catch crops), apply animal manure or apply materials as composted household-, garden- or park waste. An option is also to apply sludge. Common for these products are, that they are received for free. To compete with the carbon sources above, the price of plant based biochar must be very low. A pointe could be that the energy production (or CO_2 quotas) must pay for the pyrolysis process and plan. The effects must be well documented and demonstrated in practice, so that biochar is used where the benefits are optimal. It is suggested, that getting the best effect to soil improvement and root development, the plant based biochars should be placed at soil depths of 20-40 cm in sandy soils with low water holding capacity. There is a need for development of application equipment. As for other input materials to arable land, **it's of great importance to have limit values for the content of heavy metals and other pollutants, to ensure a soil of high quality in the future with no limitations in use.**

REFERTIL BIOCHAR FEASIBILITY CASE STUDY

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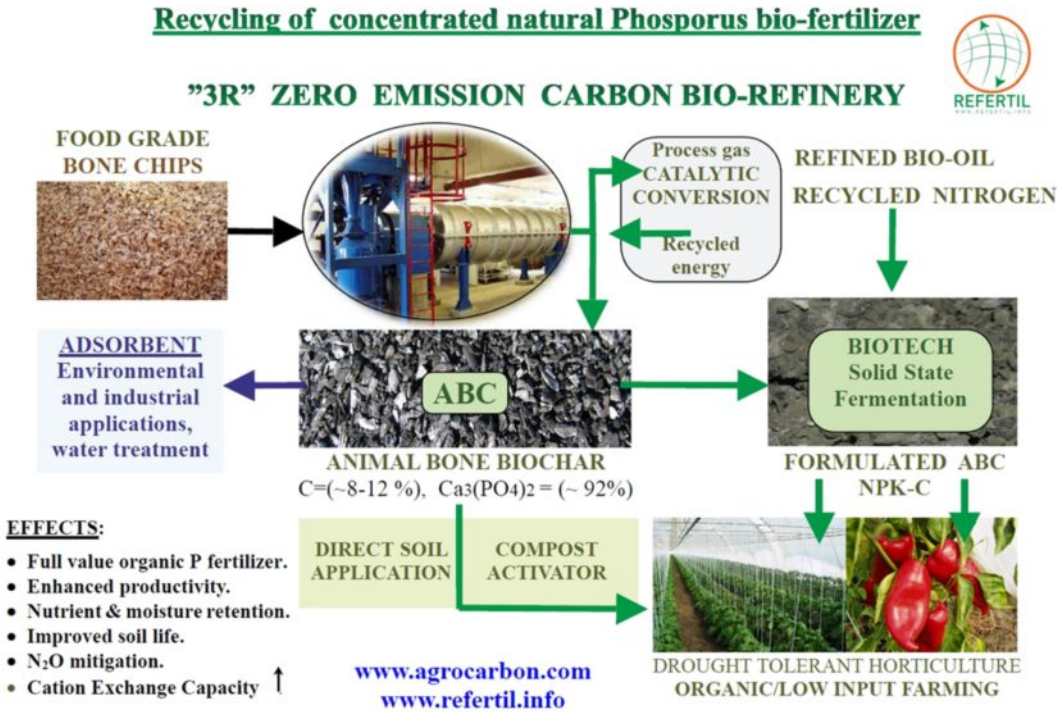
Feasibility study is a tool for investor for estimation of project. It is a process of evaluating specific investment decisions. It is core document for decision makers; managers and financial institutions (loan providers). Assessment of market for produced animal bone biochar ABC as organic fertilizer for horticulture is important. Purpose of feasibility study is to provide data about technology, equipment and infrastructure, investment costs, needed approvals and to show performance indicators to potential investors. Feasibility study estimates eligibility of investment in equipment and infrastructure for biochar production by capacity of: 20.800 t/y bone meal category 3 with 12.000 t/y bone charcoal ABC production (large scale) and 3.500 t/y meat bone meal (small scale). Economic calculations, market research, detailed analysis for investment in new products: Profit and loss account, Payback period – risk and liquidity of the project (ROI).

Preliminary calculations showed that investment in pyrolysis plant with capacity 28.000 t/y is feasible with ROI 3,6 years. Full scale industrial performance with ROI less than 5 years would attract investors. Most difficult is evaluation of ABC biochar market price, because of uncertainty in agronomic value and in whether a carbon market might develop for biochar deployment. **Detail feasibility study will be done in autumn 2105 with sensitivity analysis simulation of important parameters to evaluate changing market conditions.**



CONVERSION OF SCIENCE INTO INDUSTRIAL PRACTICE: BIOCHAR SCALE UP, INDUSTRIALIZATION AND AUTHORITY PERMIT

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The goal of the biochar scale up is to produce and supply safe, premium quality and market competitive concentrated Phosphorus product with unique and high added value application characteristics for the horticultural and adsorption industrial users. This will be achieved by zero emission recycling of the Phosphorus from food grade animal bone grist that is available in economical industrial scale in European dimension.

Biochar TRL technology readiness levels Commission Decision C(2013)8631	TRL Implementation factor %	TRL Implementation risk %
Research and development steps TRL 1-3 IDEA (basic principles, technology concept formulated)	0-1%	99-100%
TRL 4 technology validated in LAB	0-3%	97-100%
TRL 5-6 PILOT technology validated and demonstrated (high technical risk/full commercial risk)	10-25%	90-100%
RTD risk break-even point		
TRL 7 system PROTOTYPE demonstration in operational env.	60-75%	40-70%
TRL8 FIELD DEMO system complete and qualified	**75-90%**	**15-25%**
Ultimate RTD stage **conversion of science into practice =** **TRL 9 competitive manufacturing**	**95-99%**	**1-5 %**

Natural science scale up system

Revolutionary innovative thermal process with specific horizontally arranged indirectly heated rotary kiln construction for efficient and high yield production of 'ABC' animal bone biochar recycled phosphorus fertiliser. The innovative construction provides highly efficient indirect heat transfer, energy efficiency and maintenance of true reductive thermal processing conditions with high material core temperatures up to <850°C under negative pressure conditions and high feed flexibility. The efficient process technology providing safe and high quality ABC output product performance.

The **primary output product is "ABC" Animal Bone bioChar** at 6000 t/y capacity, containing 92% pure apatite, high concentrated calcium phosphate mineral, a specific and unique characteristic macro porous P fertilizer with formulated, N+K+micronutrients adapted and controlled "as plant needs" Phosphorus release performance.

The 3R key enabling technology and ABC products are **completed and qualified by 2015** under EU FP7 REFERTIL 289785 programme and ready for market competitive manufacturing in full industrial operational environment for high added value processing of 10,000 t/y bone meal inputs. Beyond REACH, valid EU and MS national industrial norm, standards, regulations and Authority industrial permits to be applied, both for biochar production and soil application above one ton/year capacity.

ORGANIC AMENDMENTS TO IMPROVE DISEASE SUPPRESSIVENESS OF SOILS

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Soil-borne pathogens can cause serious economic damage in agricultural crops. However, disease resistant cultivars are not always available and chemical control has environmental draw backs. Soil disinfestation as well as preventive pesticide application is often not allowed anymore. Improving plant resilience and enhancing soil suppressiveness against diseases are environmentally friendly strategies to grow healthy crops. The addition of organic (waste) products in soil is one management strategy that supports soil quality as well as soil suppressiveness against certain diseases.

In our research we demonstrated a reduction in Pythium infection in tomato plants when compost was added to potting soil. Disease reduction varied from 30-60% in different experiments. Biochar was less effective in reducing Pythium infection than compost. However, addition of a microbial inoculant, an antagonistic strain of *Pseudomonas chlororaphis*, improved suppressiveness of the biochar. These results show that compost as well as the addition of a microbial inoculant to potting soil or supplied in animal bone char, will enhance the disease suppressiveness of the growing system.

Different products delivered by REFERTIL partners. Picure 2-8: Different compost products, Picture 9: Animal Bone bioChar (ABC), Picture 10: Plant based biochar (PBC)

EFFECTS OF BIOCHAR AND COMPOST APPLICATIONS ON FORMATION AND FUNCTION OF MYCORRHIZAL SYMBIOSES

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In the REFERTIL framework the Leibniz University of Hannover has the objective to combine biochar and compost products with inocula of arbuscular (AMF) and ericoid mycorrhizal fungi (ERMF), with the aim to improve plant tolerance against abiotic and biotic stress.

A number of isolates of arbuscular and ericoid mycorrhizal fungi are tested in combination with biochar and compost in tagetes and rhododendron pants regarding mycorrhizal colonization and functioning. Only in special combinations of composts/biochars with mycorrhizal fungi a hindered mycorrhizal formation could be detected. In the overall picture this has no meaning because these combinations can be avoided. Functioning of mycorrhizal fungi was defined as growth promotion by AMF and anti-phytopathological effects of ERMF. **Composts and biochars can support plant growth and health by their nutrients and anti-pathogenic effects. In special combinations with mycorrhizal fungi a synergistic increase of these effects was observed.** The living micro-organisms in composts obviously play a role in these interactions. An important technical aspect for the use of AMF/compost products in plant production is the shelf life of AMF inoculum in compost: final mixtures must be stored for some time before distribution and use on farm. Storage experiments showed that AMF inoculum could be stored in mixture with composts up to 3 months without loss of infectivity. The final conclusion can be that selected mycorrhizal fungi can be combined with composts or biochars without problems and usefully applied in agri- and horticulture.

Greenhouse bioassay with Rhododendron plant

Mycorrhiza colonizing roots under magnification of light microscope

COMPOST HARMONIZATION IN THE EU: THE REFERTIL CONTRIBUTION

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REFERTIL Consortium has been developing from 2011 to 2015 a wide range of scientific technical and dissemination activities related to Composting and Pyrolisis technological assessment and development and Compost and Biochar evaluation and improvement.

PARAMETERS	CRITERIA
Organic Matter	>15% on dry matter weight
Pathogens	No *Salmonella* sp. in 25 g ; <1000 CFU/g for *E. Coli*
Minimum stability	15 mmol O2/kg organic matter/h
Weeds and propagules	<2 viable weed seeds/liter
Impurities	0.5% > 2mm
Zn (mg/kg)	600
Cu (mg/kg)	200
Ni (mg/kg)	50
Cd (mg/kg)	1.5
Pb (mg/kg)	120
Hg (mg/kg)	1
Cr (mg/kg)	100
PAH16 (mg/kg)	6

Compost quality criteria, EoW Technical Proposal for Compost and Digestate, December 2013.

Hundreds of organic residues and by-products as well as compost and biochar samples have been sampled and analysed, 23 composting facilities mainly treating EoW kind of input materials have been visited and evaluated with the open and fruitful collaboration from owners and managers. One of these extensive works main objectives is to collect first hand quality information about these technologies for converting organic materials into high quality final products like compost and biochar related and the optimal conditions for its use mainly in agricultural application.

REFERTIL Consortium has also performed a close follow up as well as collaboration with the development of the *"EoW Criteria for Compost and Digestate"* that ended in December 2013 with the non-applied Final Proposal. In consequence **REFERTIL** considers that the objectives of the EoW initiative are far from being attained, considering *that the objective of end-of-waste criteria is to remove the administrative burdens of waste legislation for safe and high-quality waste materials, thereby facilitating recycling. It is achieved by requiring*: (i) *high material quality of recyclables, (ii) promoting product standardisation and quality assurance, (iii) improving harmonisation and legal certainty in the recyclable material markets.*

REFERTIL Consortium has been and will be developing field, lab and cabinet reports and technical guidance documents that will be summarised in September 2015 Reports related with Composting process and Compost standardisation with the aim of contributing to the imperative need of an harmonised frame at EU level.

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