BIOFECTOR Report Summary

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Periodic Report Summary 3 - BIOFECTOR (Resource Preservation by Application of BIOefFECTORs in European Crop Production)

Project Context and Objectives:

BIOFECTOR is an interdisciplinary research project with the final goal to develop novel approaches for agricultural use of so-called bio-effectors (BEs), comprising microorganisms and bio-active natural compounds with the ability to improve growth, nutrient acquisition and stress tolerance of crops, without significant direct input of nutrients. The BEs are employed to optimise the productivity and particularly nutrient use efficiency of alternative fertilization strategies to promote a more sustainable agricultural production e.g. by organic farming, use of recycling fertilizers or by fertilizer placement close to the roots, as alternatives for the prevailing use of mineral fertilizers, mainly produced by direct or indirect exploitation of non-renewable natural resources. It is expected that the combination of selected BEs, compatible with appropriate alternative fertilisation strategies, will reduce the variability of external factors affecting the efficiency of BEs in plant growth promotion, thereby improving the reproducibility of beneficial BE effects, which is still one of the major limitations for BE application in agricultural practice. Maize, wheat and tomato were selected as representative target crops.

Bio-effectors with putative plant growth-promoting potential are provided by five European companies with expertise in selection, formulation and production of BE products. For products with a proven record of plant-growth promotion (PGP), an international expert team of soil microbiologists, plant physiologists and agronomists characterizes the principle modes of action and the underlying physiological and molecular mechanisms at the molecular and physiological level as well as potential impacts on native soil-microbial populations to consider putative effects on soil ecology and bio-safety. The efficiency of the selected BEs for improvement of alternative fertilization strategies is evaluated in standardized model experiments under controlled environmental conditions, followed by small-scale field trials. Apart from single BEs, also synergistic effects of product combinations are investigated. Phosphate (P) was selected as a major target nutrient with limited availability in soils, since plant adaptations towards improved P acquisition are matching many plant traits promoted by interactions with BEs (e.g. root growth promotion, changes in rhizosphere chemistry towards mobilization of nutrients). After the initial screening phase, successful products are finally assessed within the “BIOFECTOR International Field Testing Network”, providing standardized field testing facilities in nine countries under the geo-climatic conditions representative for European agriculture. The field-testing network also provides the base for public demonstration trials and the data for a cost-benefit analysis of the newly developed fertilization strategies in comparison with conventional practice in the second phase of the project. Further scenario and/or simulation analyses of representative approaches will be conducted to depict the economic efficiency under varying (world) market and price conditions to approve their economic viability and sustainability.

Perspectives for patenting, registration, and international marketing of novel BE products in different countries are investigated and developed in close cooperation of all contributing project partners. Training activities comprise organisation of training courses on application technology for BE products for extension service and farmers, as well as student workshops, master and bachelor programs on BE research. A public data base, collecting information on commercially available BE products, application modes and targets as well as evaluations in the scientific literature is installed as an information guide for farmers and scientists and as a platform for producers of bio-effectors to present

products with a proven record of efficiency.

Project Results:
In total 38 BE-products have been analysed for potential applications in alternative fertilization systems. Investigations of microbial PGP effects under controlled conditions, revealed a central role of root growth promotion in all tested plant species for 23 microbial BEs belonging to 14 fungal and bacterial genera. PGP effects were mainly expressed under conditions of moderate P availability, easily accessible by root proliferation. This was not the case on low P soils or after supply of sparingly-soluble inorganic P fertilizers (ashes, slugs, rock-phosphate), indicating a lack of P-solubilizing potential. However, with the same type of P fertilizers, many of the investigated microbial BEs (9 out of 12 tested products) showed strong PGP potential when the plants were supplied with ammonium instead of nitrate as major nitrogen (N) source. Ammonium promotes the plant´s own P-solubilizing potential by induction of rhizosphere acidification and stimulation of root hair development. This scenario promotes the expression of synergistic BE/plant/fertilizer effects on root growth and rhizosphere chemistry, improving, both, spatial and chemical acquisition of P and other nutrients on neutral and alkaline soils. Obviously, N fertilization management can be employed as a tool to promote the efficiency of plant-BE interactions.
With respect to utilization of organic recycling fertilizers, positive responses to BE inoculation were mainly observed in combination with composted animal manures, particularly expressed in tomato production systems, with highly profitable yield effects. The responses can only partially be attributed to nutritional interactions, since strong beneficial BE effects have been detected also in nursery cultures with highly sufficient nutrient supply and may be explained by BE-induced mitigation of inhibitory side effects of manure fertilization. No comparable PGP effects have been detected so far for most organic recycling fertilizers based on composts, digestates or sewage sludge.
The expression of microbial PGP was highly dependent on the efficiency of root colonization and was consequently inhibited by a wide range of environmental stress factors, affecting root growth and function. Accordingly, beneficial BE effects were more strongly expressed in horticulture (tomato), at least partially performed under protected greenhouse conditions, while much greater variability was recorded in agricultural cropping systems. Therefore, stress protection was a major issue addressed by (i) selection of stress-resistant microbial strains and (ii) use of non-microbial BEs as stress protectants. Efficient protective effects against cold, drought and salinity, already tested under field conditions, were recorded for novel combination products based on plant-, and seaweed-extracts, triggering a pre-adaptive expression of stress defence systems, already before onset of the stress treatments, and supplementing micronutrients (zinc, manganese), required for protective mechanisms against oxidative stress. The mode of action, based on signal and micronutrient functions, requires only low application doses with promising economic perspectives. First combination products developed with micronutrients and selected strains of Bacillus and Trichoderma, demonstrated superior PGP performance based on synergistic interactions under cold stress and in combination with ammonium-based fertilizers.
For a more flexible and economic integration of BE application strategies into agricultural practice, the development of granulated microbial BE formulations provides a perspective for co-applications within sowing techniques and placement of fertilizers, associated with improved root colonization as compared with conventional seed dressings. The same holds true for the synergistic BE effects with ammonium fertilisers, providing integration perspectives into modern ammonium-based fertilizer placement strategies, increasingly employed to reduce N losses and to improve fertilizer use efficiency. From an ecological point of view, all investigated microbial inoculants significantly influenced the composition of native rhizosphere-microbial populations. However, different soil types had a much stronger impact on soil microbiomes than the inoculation with microbial BEs. A more serious ecological issue may be associated with the detection of numerous genes for resistance against antibiotics in some manure based organic recycling fertilizers.

Potential Impact:
The broad screening approach employed within the project, covering a wide range of BEs selected from the most important BE classes, tested on different soils under a wide range of different fertilization regimes, makes it possible to define potential perspectives but also the limitations of BE/fertilizer combinations in the addressed fields of

application. A meta-study, covering currently up to 100 experiments conducted within the project, will provide a comprehensive data set for final interpretation of results of agronomic interest, frequently not statistically significant by analysing single field experiments.
Most promising perspectives identified so far comprise: (i) use of novel combination products based on seaweed and plant extracts as stress protectants, (ii) the role of nitrogen and micronutrient fertilization in optimizing plant-microbial BE interactions, (iii) perspectives to develop novel multi-functional BE products by exploitation of synergisms (see I and ii), and (iii) perspectives for more efficient and economic BE application techniques in agricultural systems. However, apart from promising microbial BE effects on utilization of manure-based organic fertilizers, successful BE strategies in organic farming still represent a major challenge due to the lack of standardized fertilizers, which further increases the number of potentially interfering variables.
Based on the information provided by the project, farmers will be able to perform a more targeted selection of suitable products for their specific culture systems including also information on yield potential, expected economic benefits and ecological impacts. In those fields of horticultural and agricultural production identified as suitable for successful implementation of BEs into the production systems, substantial improvements in fertilizer use efficiency and reductions of fertilizer inputs, greenhouse gas emissions, as well as saving of energy and production costs can be expected.
Since many of the most promising microbial BEs with PGP potential, also provide proven records of bio-control activities against soil pathogens, a beneficial impact on disease resistance may be expected as a side effect, associated with reduced consumption of pesticides. Taken together, this can be translated into consumer benefits in terms of price stability, product quality and product safety.
The SME partners are provided with a unique opportunity for comparative evaluation of the their product portfolio, even in combination with BE products from other producers under a wide range of agricultural production conditions in Europe, using the infrastructure of the project for standardized lab and field testing. Apart from the originally intended use of the BE products, this unravelled novel, yet unknown properties, already resulting in first patent applications.
From the scientific point of view, scientists SMEs, extension services and farmers are brought together with mutual benefits arising from the multidisciplinary and integrated research approach. Internationally recognized research experts in soil science, microbiology and plant science share their knowledge to improve the understanding of BE effects, from molecular to field scales. The opportunity to investigate a wide range of different BEs under different production conditions in a comparative way, contributes to a better understanding of the frequently rather hypothetic modes of action in plant-BE interactions. The project also provides an excellent interdisciplinary education platform for students and young scientists with numerous options to contribute as scientific helpers, exchange students bachelor or master student or on PhD and post-doc positions.

List of Websites:
www.biofector.info

Related information

Documents and Publications	periodic3-biofector-periodic-report-3-final-chapter1.pdf

Contact

Stephan Dabbert, (Rektor)
Tel.: +497114590
Fax: +4971145924050
E-mail

Subjects