Brussels, 12 May 2023

COST 052/23

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action "Beneficial root-associated microorganisms for sustainable agriculture" (ROOT-BENEFIT) CA22142

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action Beneficial root-associated microorganisms for sustainable agriculture approved by the Committee of Senior Officials through written procedure on 12 May 2023.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA22142
BENEFICIAL ROOT-ASSOCIATED MICROORGANISMS FOR SUSTAINABLE AGRICULTURE (ROOT-BENEFIT)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to evaluate the potential of various levers and propose strategies for the integration and improvement of the services provided by the beneficial root-associated microorganisms to agriculture. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

OVERVIEW

Summary
Beneficial root-associated microorganisms, including arbuscular mycorrhizal fungi, nodule-inducing nitrogen-fixing rhizobia, and plant growth-promoting bacteria/fungi, are key players for crop productivity in low-input systems. Identification of environmental and genetic determinants controlling their interactions with crops is paramount for the development of a more sustainable agriculture, and this requires multidisciplinary research approaches. However, the research field remains fragmented and beneficial microorganism interactions with plant roots are often overlooked in agricultural management practices or in breeding programs. ROOT-BENEFIT aims to bring together, specialists of these different types of beneficial interactions working at different levels of study, together with socio-economic actors to create a network able to: i) sum up and disseminate the current knowledge on agronomic, environmental and economic criteria characterizing the services provided by beneficial root-associated microorganisms, ii) perform meta-analyses with existing datasets, iii) identify gaps in the current knowledge and define future research priorities, iv) propose methodologies and strategies for implementing or improving crop interactions with beneficial root-associated microorganisms in agriculture, v) propose recommendations on microbial applications to inoculant producers, policy-makers and end-user farmers. Overall, ROOT-BENEFIT will strengthen the European research capacity and leadership on beneficial root-associated microorganisms, and facilitate knowledge transfer to socio-economic actors and inclusiveness towards European and Mediterranean countries.

Areas of Expertise Relevant for the Action	**Keywords**
● Biological sciences: Symbiosis ● Agriculture, Forestry, and Fisheries: Agriculture related to crop production, soil biology and cultivation, applied plant biology, crop protection ● Agriculture, Forestry, and Fisheries: Sustainable Agriculture ● Biological sciences: Plant biology, Botany ● Biological sciences: Microbiology	● beneficial root microorganisms ● plant-microbe symbioses ● ecosystem services ● agriculture

Specific Objectives
To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination
● Compile and disseminate current knowledge on plant interactions with beneficial root-associated microorganisms, identify gaps in knowledge and define future research priorities.
● Facilitate the visibility and access to existing European beneficial root-associated microorganism resources and to coordinate development of resources useful for studies on beneficial root-associated microorganisms.
● Analyse the limitation of current methods and propose their improvement to better describe beneficial root-associated microorganism interactions and to better evaluate the services they provide to crops under field conditions.
● Evaluate the potential of various levers for improving plant interactions with beneficial root-associated microorganisms under various soil and climate conditions and propose strategies for future research and development on these levers.
● Make recommendations about beneficial root-associated microorganism inoculant selection, application, and quality control for producers and policy-makers.

Capacity Building

● Establish a large multidisciplinary network involving microbiologists experts in plant-microorganism interactions, plant physiologists and geneticists, ecologists and agronomists, from both public and private sectors, to promote the exchange of expertise and know-how on beneficial root-associated microorganisms. Facilitate contacts with international companies/SMEs, policy-makers and end-users.

● Train students, Young Researchers and Innovators and stakeholders. Promote the emergence of new research capacities and facilitate the transfer of knowledge in relation to the use of beneficial root-associated microorganism interactions.

● Raise awareness of the economic sector, policy-makers, end-users as well as the general public, notably of the younger generation, about the relevance of using beneficial root-associated microorganism interactions to reach a more sustainable agriculture.

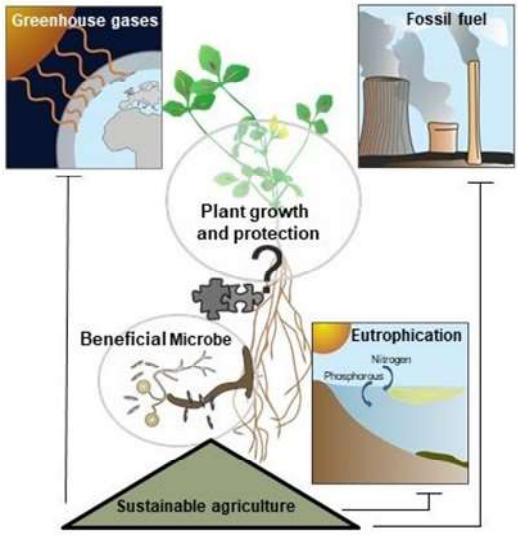
TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. SOUNDNESS OF THE CHALLENGE

1.1.1. DESCRIPTION OF THE STATE OF THE ART

The "First Green Revolution" entailed intensive agricultural practices aiming to increase agricultural production[1]. The development of high yielding varieties capable of capitalising on synthetic inputs (e.g. fertilisers and pesticides) was a key to these revolutionary processes for agriculture. While this allowed a fast increase in food production and food security, it came with a cost for the environment and society. It is now admitted that intensive agriculture and food production has multiple negative impacts both on and off the farm, including severe decreases in natural and grown biodiversity, increases in fossil fuel consumption and greenhouse gas emissions, eutrophication of aquatic systems…[2]. Yet none of these damages are directly reflected in the price of food and consumers are paying in other hidden ways, such as taxes related to pollution clean-up or health care costs. In addition, a "legacy" of costs caused by climate change will have to be paid for by future generations.



Plants & microorganisms. The use of beneficial root-associated microorganisms to sustain plant nutrition and protection as an alternative to fertilizers and pesticides contributes to decrease fossil fuel consumption, greenhouse gas production and water pollution.

An alternative to this situation is the promotion of cropping systems that rely on ecological services, such as those provided by beneficial root-associated microorganisms[3-5]. The implementation of these agroecological principles has the potential of helping farmers to use more environmentally friendly practices while safeguarding profitable yields and/or increasing crop's nutritional value. Moreover, beneficial root-associated microorganisms have the potential to make soil and plants more resilient to the increased frequency of extreme events and emergence of new biotic stresses associated to climate change.

Root microbial communities, collectively referred to as the root microbiota, populating the root soil interface, benefit from the organic matter released by plants in the vicinity of their roots, a portion of soil defined as the rhizosphere. In turn, members of this microbiota can positively affect their host plants. For instance, the plant growth promoting (PGP) microorganisms can enhance nutrient mobilisation by plants and provide pathogen and pest protection to their host. By facilitating nutrient and water uptake, beneficial root-associated microorganisms have also been shown to stimulate plant tolerance to abiotic stresses, such as drought[6]. There is currently a high interest to better understand how beneficial root-associated microorganisms can help maintaining plant growth and yield in the context of global changes, which will increase frequencies of heat waves and drought stress, but which will simultaneously provide an increased availability of atmospheric CO_2 predicted to benefit symbiotic plants due to increased photosynthetic efficiency[7]. Root microbiota provide additional ecological services such as improved soil aggregation and carbon sequestration, which are important for the sustainability of agriculture. Among these microorganisms, arbuscular mycorrhizal (AM) fungi and nodule-inducing nitrogen (N)-fixing rhizobia are the best characterised. Yet what emerged in the last decade is a far more complex picture of interactions occurring at the root-soil interface: multiple microbial species are capable of interacting with and providing benefit to their host plants by mechanisms transcending the "traditional" growth promotion. These microorganisms, defined here as beneficial root-associated microorganisms, are the focus of this Action.

Taken together, beneficial root-associated microorganisms emerge as key players for crop productivity in low-input systems, and identification of environmental and genetic determinants controlling their interaction with crops is paramount for the development of a more sustainable agriculture that would allow the maintenance of stable yields over time.

Despite this body of knowledge, the implementation of agroecological principles and the transition towards more sustainable practices relying on ecological processes provided by beneficial root-associated microorganisms requires redesigning cropping systems and the whole supply chain, and thus **the active participation of all the range of stakeholders involved**[8].

In Europe there is currently a large research community which studies plant-microorganism interactions, particularly the establishment and functioning of symbiotic interactions and the ecology of root microorganisms.

Nevertheless, this **research community is fragmented** and there is a **low level of interactions across the stakeholders limiting** the research coordination and **transfer of knowledge** from the academic sector to industries, SMEs, end-users such as farmers or policy-makers.

1.1.2. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The main aims of **ROOT-BENEFIT** are: **i)** to structure the European research community on beneficial root-associated microorganism interactions in order to favour networking, strengthen the European research capacity, and facilitate knowledge transfer to socio-economic actors; and **ii)** to evaluate the potential of various levers (described below) and propose strategies for the integration and improvement of the services provided by the beneficial root-associated microorganisms to agriculture.

Several barriers currently hamper the implementation of beneficial root-associated microorganisms in more sustainable agricultural practices.

Challenge 1. The European research community is fragmented:

The European research community working on this topic is mainly organized by **i)** the type of beneficial root-associated microorganism studied and **ii)** the level of study (molecular, cellular, eco-physiological, field, cropping system, …), while exploiting the potential of beneficial root-associated microorganisms in agriculture requires multi-scale and multidisciplinary research approaches. This is reflected in the European/international academic societies and scientific conferences that follow the same pattern (e.g. ICOM, iMMM, ENFC, Biostimulants…conferences).

Challenge 2. Research on beneficial root-associated microorganisms for agriculture is under-represented in European calls:

Despite their potential for application in agriculture and to fulfil the general aims of the European Green Deal (reducing net greenhouse gas emissions by at least 55% by 2030) and notably those of the Farm to Fork strategy (reducing fertilizer use by at least 20% by 2030 or increasing organic farming to 25% of total farmland by 2030), beneficial root-associated microorganisms are relatively under-represented among the topics of recent European calls for grant applications. In the last years, strong emphasis has been put on studies related to soil microbiota and biocontrol agents. Although beneficial root-associated microorganisms fall into these microorganism categories, the specificities of beneficial root-associated microorganisms make them generally not being characterized in global functional studies of microbiota and/or not considered for their dual role in nutrition and protection against pests and diseases. This has largely prevented both the scientific community and stakeholders from fully deciphering and benefiting from the potential of these beneficial plant-microorganism interactions.

Challenge 3. Limited tools and methodologies for the characterisation of microbial communities:

One of the current challenges for ecological studies of beneficial root-associated microorganisms is to understand how variations in the quantity and composition of the soil and of root communities influence the benefits they provide to crops. Nowadays, the description of the microbial community composition is mainly achieved by metabarcoding and microorganism isolation and characterization. These approaches have proved to be very effective in describing multiple samples in a timely fashion. Yet, they suffer from a lack of resolution in dissecting intra genus and species diversity among microorganisms. These data may be critical when considering microbial functions that deliver ecological services to the agroecosystems.

Challenge 4: Limited knowledge about complex interaction outcomes:

Despite extensive knowledge on the molecular mechanisms of the interactions between plants and individual beneficial root-associated microorganism in controlled conditions, multipartite interactions (e.g. combined rhizobia + AM fungi + other PGP microorganisms or biocontrol agents) and the impact of the environment (e.g. mineral nutrient availability, temperature, atmospheric CO_2 concentration) on these interactions have barely been analysed. This limits the translational exploitation of the current knowledge into agriculture, as well as predictions about the impact of climate changes on the root colonization by these microorganisms and on the efficacy of ecological services they provide.

Challenge 5: The potential of beneficial root-associated microorganism for climate change mitigation and for plant resilience needs to be better integrated:

Global warming and other climate changes associated with human activities lead to a combination of various threats affecting plant growth and agriculture yields. The role of beneficial root-associated microorganisms in these fast evolving and complex environmental conditions needs to be evaluated in more depth through integrated approaches at different scales. Noteworthy, endosymbiotic interactions are predicted to benefit more from the increased atmospheric CO_2 availability whereas AM fungi may promote an increased water acquisition due to their ability to explore large soil volumes and to transport water. However, climate changes also directly bring some drawbacks on endosymbiotic interactions such as in relation to drought. In addition, root and rhizosphere microorganisms can contribute to stabilization of soil organic matter. Better understanding and managing the potential of root-associated microorganisms on soil carbon and nutrient storage is particularly relevant in organic matter-poor cropland soils as found in many regions in Europe.

Challenge 6: The potential for plant breeding to improve beneficial microbial interactions has not been exploited:

The genetic variation existing in cultivated plants can greatly impact both the capacity of beneficial root-associated microorganisms to colonize roots and the capacity of plants to benefit from these interactions. This represents an attractive avenue to enhance relationships between plants and beneficial root-associated microorganisms in agriculture. However, conventional breeding strategies have not explicitly considered the interactions with beneficial root-associated microorganisms. To achieve this, first appropriate agricultural practices and secondly specific tools to evaluate the plant responsiveness to these beneficial root-associated microorganisms, are required.

Challenge 7: Scientific results and recommendations often do not reach end-users:

It is well known that several conventional agricultural practices, such as tillage or high levels of chemical fertilization, reduce both the diversity in the root microbiota and interactions with AM fungi and N-fixing root nodule bacteria[9]. Beneficial root-associated microorganisms are thus likely to express their full potential in low-input and low soil-disturbance cropping systems. The combination of both low-input and low soil-disturbance practices remains however marginally used in Europe.

Challenge 8: The commercialized beneficial root-associated microorganisms do not always meet the expectations for long-term soil management:

Beneficial root-associated microorganisms are sold in Europe either as biostimulants or as biocontrol agents. Field inoculation with rhizobia has been used since a long time as it is indispensable for the establishment of the N-fixing symbiosis in legumes when the compatible rhizobia are absent in soils (e.g. for growing soybean in Europe). Inoculation with AM fungi and PGP bacteria and fungi is more recent, but represents a fast-growing market. However, there is a strong variability in the quality of the inoculants on the market, both in terms of quantity of living microorganisms and of their efficacy under field conditions. This leads to a risk of increasing scepticism of farmers for using beneficial root-associated microorganism inoculants. Beside the quality of inoculants, there is a current lack of ecological consideration relating to microorganism selection, such as the evaluation of their persistence, competitiveness and relative efficiency in different soils, leading to a risk of soil pollution by highly persistent, highly competitive, and lowly efficient strains[10].

1.2. PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1. APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE OF THE ART

ROOT-BENEFIT aims to bring together specialists of different types of plant interactions with beneficial root-associated microorganisms, working at different levels of study, as well as socio-economic actors, in order to create a network able to perform the research and development (R&D) needed for the better integration of these interactions in agriculture. **ROOT-BENEFIT** will thus strengthen the European research capacity and leadership, facilitate research consortium applications to future European calls, and reinforce or create interactions between academic and companies to maximize innovations, as well as disseminate information and innovative practices to end-users **(Response to challenge 1 and 7)**.

ROOT-BENEFIT will facilitate coordination of European research efforts, also avoiding costly and time-consuming overlaps that may exist between research projects running in different countries **(Response to challenge 1)**. Moreover, **ROOT-BENEFIT** will highlight the European research potential on beneficial root-associated microorganism interactions and propose innovative research topics for future European calls through national representatives of each member country **(Response to challenge 2)**.

ROOT-BENEFIT will coordinate efforts to improve and disseminate operational procedures to describe the composition of microbial communities at the genus/species level and to characterize the efficiency of services provided by beneficial root-associated microorganisms, in particular under field conditions **(Response to challenge 3)**.

Through exchanges between a multi-disciplinary group of academic research scientists together with various types of private stakeholders, **ROOT-BENEFIT** will prioritise gaps to be filled in future research initiatives, as well as required strategies and methodologies **(Response to challenge 4 and 6)**. In particular, **ROOT-BENEFIT** will define and propose strategies to facilitate the simultaneous selection of responsive crop cultivars and isolation of efficient microorganism populations under prevailing cultivation conditions. Ideally, beneficial root-associated microorganisms should be co-selected with plant responsive genotypes. Such co-selection still requires a conceptual framework before setting-up proof of concept studies **(Response to challenge 6)**. **ROOT-BENEFIT** will facilitate the creation of a fully skilled consortium tackling these essential research questions in future European/transnational calls.

ROOT-BENEFIT will critically review the literature and provide meta-analyses as well as comprehensive summaries of the current knowledge on the different agricultural practices that are favourable or detrimental for plant interactions with beneficial root-associated microorganisms, and disseminate the results to the different types of stakeholders, in particular breeders, farmers and more generally towards the civil society (**Response to challenge 7**).

Beyond the current EU regulation 2019/1009, **ROOT-BENEFIT** will define criteria for selection of beneficial root-associated microorganisms for inoculation, including long-term inoculation management considerations, as well as quality control standards for high quality inoculants. **ROOT-BENEFIT** will disseminate recommendations towards the different types of stakeholders, in particular policy-makers, inoculant producers and farmers as end-users **(Response to Challenge 8)**.

ROOT-BENEFIT will facilitate innovations, such as the development of soil microbial diagnostics, inoculant selection and crop breeding through:

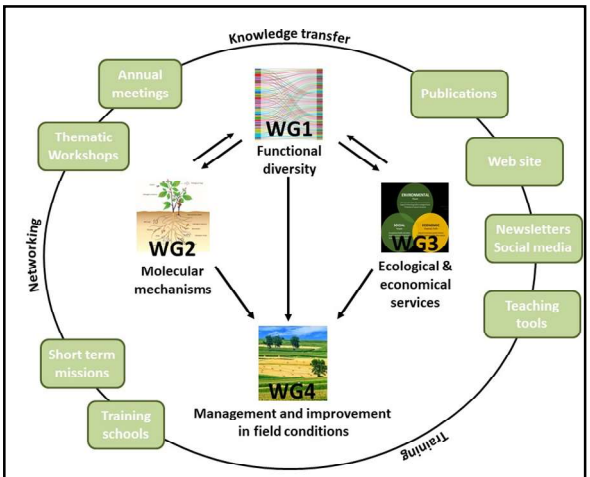
1) tackling current methodological limitation in characterization of root microbial communities (**Response to challenge 3**);

2) defining environmental factors that affect the plant - beneficial root microorganism outcomes (**Response to challenge 4**), including in the context of climate changes (**Response to challenge 5**);

3) defining conceptual frameworks allowing a simultaneous co-selection of the plant and microbial partners (**Response to challenge 6**).

The participation in the Action of actors from both academic and industrial sectors will 1) allow bringing industry concerns and bottlenecks into academy, 2) ensure transfer of relevant knowledge from the academy to the industrial sector, and 3) stimulate innovative R&D in private companies.

To address the challenges, four Working Groups (WG) have been identified. **WG1** will focus mainly on **methodologies to characterize the functional diversity of beneficial root-associated microorganism populations**, with an emphasis on meta-analyses of currently available data and coordination of future resource/tools development. **WG2** will focus on **molecular mechanisms underlying the interactions with the beneficial root-associated microorganisms**, with an emphasis on the effect of multi-partite interactions and resilience towards stressful environmental conditions**. WG3** will focus on the **ecological and economic services** provided by beneficial root-associated microorganisms. **WG4** will focus in **identifying levers to improve services** provided by beneficial root-associated microorganisms in agriculture.



Pert chart of the ~~BOOST~~ROOT-BENEFIT Action, where interactions between WGs and feeding of main COST activities (Knowledge transfer / Networking / Training) are highlighted

The WG1, 2 and 3, addressing questions on beneficial root-associated microorganisms at different levels, will provide results/knowledge/meta-analyses to feed the WG4. The WG4 will integrate all Action results and link them to stakeholder needs and requests.

1.2.2. OBJECTIVES

1.2.2.1. Research Coordination Objectives

ROOT-BENEFIT research coordination objectives are:

- To compile and disseminate current knowledge on plant interactions with beneficial root-associated microorganisms, identify gaps in knowledge and define future research priorities. This will form a basis to promote research on plant interactions with beneficial root-associated microorganisms in the agenda of future European funding calls and to propose innovative projects to answer future national or international funding calls built on the Action theme and consortia (all WGs, challenge 1-6).
- To facilitate the visibility and access to existing European beneficial root-associated microorganism resources such as microorganism collections through generation of an exhaustive database, and to coordinate development of resources useful for studies on beneficial root-associated microorganisms (e.g. genome sequencing; WG1 and 2, challenge 1 and 2).
- To analyse the limitation of current methods and propose their improvement to better describe beneficial root-associated microorganism interactions and to better evaluate the services they provide to crops under field conditions. (WG1, 2, 3 and 4; challenge 3, 4 and 5).
- To evaluate the potential of various levers for improving plant interactions with beneficial root-associated microorganisms (e.g. plant breeding, inoculation, changes in agricultural practices) under various soil and climate conditions and propose strategies for future R&D on these levers (WG3 and 4, challenge 5 and 6).
- To make recommendations about beneficial root-associated microorganism inoculant selection, application, and quality control for producers and policy-makers (WG4, Challenge 8).

1.2.2.2. Capacity-building Objectives

ROOT-BENEFIT aims to strengthen the scientific and industrial European research community through:

- The establishment of a large multidisciplinary network involving microbiologists experts in plant-microorganism interactions, plant physiologists and geneticists, ecologists and agronomists, from both public and private sectors, to promote the exchange of expertise and know-how on beneficial root-associated microorganisms.
- Training of students, Young Researchers and Innovators (YRI) and stakeholders in Training Schools (TS) and Short-Term Scientific Missions (STSM). This will lead to the emergence of new

research capacities and facilitate the transfer of knowledge in relation to the use of beneficial root-associated microorganism interactions notably targeted on Inclusiveness Target Countries (ITCs).

- Raising awareness of the economic sector, policy-makers, end-users as well as the general public, notably of the younger generation, about the relevance of using beneficial root-associated microorganism interactions to reach a more sustainable agriculture.

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

Beneficial root-associated microorganism interactions, including N-fixing and AM symbioses, are recognized as central elements for sustainable crop production in the Horizon Europe Cooperation Work Programme (Food, Agriculture and Fisheries, and Biotechnologies). However, **there are few current European-wide projects and no current COST Actions covering the scope of ROOT-BENEFIT**, that link researchers working on this specific topic, or that promote interactions between European academic researchers and large and SMEs companies, such as the plant breeding and the microorganism inoculant industries.

Outputs of previous European and national initiatives dealing with beneficial plant-microorganism interactions will be considered as state of the art, so that **the current Action will build upon the knowledge generated by these past projects**. Of particular interest among the recent COST Actions are FA1103, entitled “Endophytes in Biotechnology and Agriculture” (2011-2015), whose aim was to identify bottlenecks limiting the use of endophytes in biotechnology and agriculture, and to provide solutions for the economically and ecologically compatible exploitation of endophytes and FA1405 "Using three way interactions between plants, microbes and arthropods to enhance crop resistance and yield" (2015-2019) that focused on effect of beneficial microbes on pest resistance. Other relevant but older Actions are 838 “Managing arbuscular mycorrhizal fungi for improving soil quality and health in agriculture” (1999-2005) and 870 “From production to application of arbuscular mycorrhizal fungi in agricultural systems: a multidisciplinary approach (2007-2011), which built the International Bank for Glomeromycota (http://www.i-beg.eu/) and edited the book on “Mycorrhizal Technology: in Agriculture from Genes to Bioproducts”; and 830 “Microbial inoculants in agriculture and the environment” (1999-2004) in which inoculant properties and quality criteria were discussed.

A number of European projects related to beneficial root-associated microorganisms have been funded in the past. Among the most recent are: EUCLEG (2017-2021), LEGVALUE (2017-2021), Diverfarming (2017-2022), SOLACE (2017-2022), MicrobiomeSupport (2018-2022), EXCALIBUR (2019-2024), and SoildiverAgro (2019-2024), Root2Res (2022-27). Project leaders will be invited to join the ROOT-BENEFIT and/or to participate to relevant workshops. Despite the fact that several of these projects had a research and innovation focus on legume plants as strategic for European protein production, they had limited emphasis either on agroecology or on the services provided by (N)-fixing rhizobia.

ROOT-BENEFIT will also connect with currently on-going European projects such as EJP soil, ELIXIR and EPPN2020, to foster synergistic interactions with soil science, data sharing and management, and plant phenotyping, respectively, as well as with European associations/producer organisations such as Eucarpia and EBIC, which promote co-operation on breeding and biostimulants use in agriculture, respectively.

Finally, duplication of activities within different European research groups and countries will be avoided thanks to the coordination and networking activity planned. To this aim, **ROOT-BENEFIT** will be inclusive in nature and will welcome all European researchers from the field interested in joining the Action.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS, EXPERTISE AND GEOGRAPHICAL BALANCE WITHIN THE COST MEMBERS AND BEYOND

To unlock the potential of beneficial root-associated microorganisms, **an interdisciplinary and multi-actor approach is needed** by grouping relevant expertise within a European network to tackle and overcome the challenges faced when improving the use of more sustainable agricultural practices. The required expertise to integrate beneficial root-associated microorganisms into agriculture is frequently

beyond the expertise and capacity of a single research group, or even country, and thus makes international networking essential to identify the most relevant biological questions and provide solutions. The emphasis of **ROOT-BENEFIT** is on **complementarities and synergies, both among the academic actors and with the socio-economic stakeholders and end-user actors such as large and small companies, agronomical technical institutes, and farmers**. These interactions will provide the basis for an efficient channelling of the exploitation of new concepts and methodologies, and guide academic research towards defining innovative R&D challenges. New collaborations arising through networking will create the opportunity of joining efforts to generate cutting-edge research and innovation outputs by sharing complementary objectives, knowledge and expertise. In addition, an efficient networking will allow us to identify overlaps and prevent redundant activities in different European countries. **ROOT-BENEFIT** will integrate a large and multi-disciplinary network so that the required complementary expertise is guaranteed to achieve the objectives.

The Action will include **researchers** specialized in beneficial root-associated microorganism interactions at various scales, ranging from molecular and "omic" sciences, plant physiology, plant-associated microbiology, agronomy, and ecology, as well as **SMEs and agronomical technical institutes**.

ROOT-BENEFIT will encompasse a multidisciplinary expertise that will be grouped into four WGs to ensure a fine dissection of the different scientific questions and subtopics and their anticipated application.

Additionally, **ROOT-BENEFIT** will advertise to invite additional participants from European and Near Neighbouring Countries (NNC) working in the research field to join the network. There will also be advertising through existing international and national networks, as well as academic societies focused on topics related to the beneficial root-associated microorganism interactions research field. In addition, scientists with specific skills at the margin of the network will be invited to join specific workshops.

Taken together, the Action will integrate participants from a large variety of heterogeneous stakeholders in order to define shared objectives and to maximize knowledge co-creation, innovation, and agronomic applications of the research results.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

ROOT-BENEFIT will be a multi-actor network incorporating the European stakeholders from the beginning to the end of the Action. Besides the **ROOT-BENEFIT** annual scientific and WG meetings, in which all stakeholders will be invited, two workshops targeted towards non-academic stakeholders will be organized. The objective is to identify industrial concerns and bottlenecks and define research perspectives that can solve them. These meetings will also aim to define end-user demands in term of inoculant key properties and/or formulations or decision-making tools.

Four main categories of stakeholders will join **ROOT-BENEFIT**:

1) **Scientists from the public and private sectors involved in R&D on beneficial microorganism interactions.** During the general meetings and workshops, an update of knowledge gained by international academic experts will be provided, as well as forum discussion on topics brought by the non-academic researchers. In addition, B to B interviews will be organized to ROOT-BENEFIT academic and private research interactions towards promoting innovation.
2) **Agricultural production industry.** Industrial developers will be more specifically involved in WG4 (see the implementation plan below) for defining scheme of strain selection and crop breeding, as well as for setting-up most relevant criteria to define inoculant properties and quality controls. The generated knowledge and resources will promote the development of new technologies including innovative use of molecular markers, inoculant selection strategy and breeding schemes, and kits/soil diagnostics to quantify efficiencies of the beneficial root-associated microorganism services notably at the field level. ROOT-BENEFIT will promote the development of crop cultivars and inoculation strategies more adapted to low-input agriculture needs, also taking into account the anticipated constraints related to climate change challenges.
3) **National and international policy-makers.** A main part of dissemination activities developed during the **ROOT-BENEFIT** Action will be dedicated to generate standards and guidelines for national and European policy-makers in order to provide missing information required for decision-making about risks and opportunities associated to translational applications related to breeding and inoculation strategies.
4) **End-users**. To secure dissemination of the results, **ROOT-BENEFIT** will interact mainly with governmental institutions, agronomical technical institutes, NGOs promoting more sustainable

agricultural practices, and farmer unions, who are themselves in direct contact and involved in the training of farmers.

Key stakeholders from each sector will be invited to be part of an Advisory Council representing all stakeholder interests. All stakeholders will have access to the generated knowledge and technologies and they will be invited to participate in all activities of the Action.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

Successful completion of **ROOT-BENEFIT** will have a great impact in under-investigated areas of the field of root beneficial microorganism interactions. The following impacts are expected to generate a transversal scientific knowledge that will be used in future European research programs:

- Creation of a multidisciplinary European network and research collaborations able to tackle scientific questions focused on an under-represented topic in European calls, the services provided by beneficial root-associated microorganisms in agriculture.
- Highlight shared socio-economic and academic research priorities, strategies and methodologies that will be provided to policy-makers to define future research orientations in relation to agroecology, notably at the European level.
- Training of the young generation of scientists and YRIs that will perform tomorrow's research and development, and benefiting from their communication skills in relation to social media activities and diffusion of scientific knowledge.

ROOT-BENEFIT is also expected to have an impact on the socio-economic partners:

- Raising the awareness of stakeholders, policy-makers and end-users regarding the role of beneficial root-associated microorganisms in agriculture, to improve their decision-making and help choosing the best technical opportunities, notably in relation to inoculant formulations and properties.
- Development by private companies of breeding programs to (co-)select cultivars efficient in low-input and/or low soil-disturbance cropping systems.
- Selection and development by private companies of inoculants composed of beneficial microorganisms/consortia efficient at the field scale, either to restore soils with poor microbial diversity or efficacy, or to grow legumes in area where their specific rhizobial partner is absent.

Ultimately, **ROOT-BENEFIT** will impact the society through its action on different stakeholders to promote the use of beneficial microorganisms to reduce pollutions and move towards a more sustainable agriculture.

3.2. MEASURES TO MAXIMISE IMPACT

3.2.1. KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

ROOT-BENEFIT is a COST Action that encompasses groups with very strong backgrounds in beneficial interactions between root-associated microorganisms and plants. **Knowledge generation** will be a pillar of the activities of **ROOT-BENEFIT**, which will be achieved through meeting/workshop brainstorming, data meta-analyses, as well as critical analyses of scientific articles on specific topics (review and opinion articles). Creating and operating this COST Action will reduce competition between European laboratories by facilitating and stimulating collaborations, and strengthening the capacity of European laboratories to tackle scientific and socio-economic challenges.

In order to provide intense **transfer of knowledge**, **WG workshop meetings** will be organized each year in addition to the annual general meetings (See table 1 for a summary of the activities). Moreover, **ROOT-BENEFIT** will also organize **workshops dedicated specifically to the points of view and needs of non-academic stakeholders.** This includes research institution administrators, public organisations, SMEs and multinational companies, NGOs, consumer organisations, academic societies, media, and journalists. **ROOT-BENEFIT** will also develop some training focused on topics and

methodologies targeted towards researchers working in private structures such as breeder and inoculant producer companies, and will encourage visits of YRI participants to private companies.

In addition, **ROOT-BENEFIT** will plan **exchanges** among laboratories to facilitate technical skill and knowledge transfer. **ROOT-BENEFIT** will prioritise YRIs exchanges, which will provide excellent occasions for European postdoctoral scientists, PhD and graduate students to learn breakthrough knowledge and techniques. **ROOT-BENEFIT** will provide advanced training for all kinds of researchers, and particularly the YRIs to improve their skills. These initiatives will also be used as a tool to promote **gender equality**.

ROOT-BENEFIT will ensure that participants from **Central and Eastern European Countries (CEECs)** join the Action. The implementation of more sustainable practices in CEECs is less developed than in Western Europe, mainly due to historical reasons. The involvement of **ROOT-BENEFIT** proposers from CEECs will help to promote knowledge transfer and popularization of agricultural practices relying in beneficial root-associated microorganisms in CEECs.

Regarding **career development**, the YRI training and exchanges to visit different laboratories across Europe will allow YRIs to build their own personal networks, increasing their mentoring and job opportunities, as well as accelerating research and innovation. Priority will be given to YRIs for oral presentations and organizing/chairing events during the **scientific workshops** of this proposal. **ROOT-BENEFIT** will enrol and train YRIs to both participate and organise public outreach activities to promote science communication. **ROOT-BENEFIT** will assign **responsibilities to YRIs** in the organization of events and activities to develop management skills that will be essential for career development. **ROOT-BENEFIT** will stimulate the organization of an **'YRI club'**, in which important questions arising during experimental work, presentations and career planning will be discussed. **ROOT-BENEFIT** will also increase the **international visibility** of the members from ITC countries, further raising their opportunities to be partners of future collaborative European projects.

3.2.2. PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The network will implement a dedicated strategy of dissemination and exploitation through internal and external missions (See table 1 for a summary of the activities). These activities will be organized through an Executive Dissemination Committee, which will be headed and composed of YRIs to favour the most efficient and active use of social media. This committee will ensure:

- an effective and sustainable **dissemination** of generated knowledge and technologies, through the communication activities targeting each type of stakeholders, within the entire Europe and Mediterranean basin.
- an **exploitation** of the Action's results by socio-economic actors to improve/develop/adopt soil microbial diagnostics, breeding, inoculation, agricultural practices, and to maintain and reinforce technological advantages over the competition outside Europe and the Mediterranean basin.
- propositions of **policies** regarding inoculant properties and quality controls by involving industrial producers, farmer end-users, academic researchers, and civil society representatives (science journalists, politics, citizens)

The dissemination and exploitation will be performed at different levels:

- **Advertising** the Action, its main objectives and expected impacts through a public website and social media to stimulate participation of academics and SME/multinational companies, the civil society (NGOs, journalists, policy-makers…), and end-users (farmers);
- **Disseminating Knowledge** to provide regular information about **ROOT-BENEFIT** outputs in the form of scientific reviews and opinion publications for researchers, public engagement, articles/videos for end-users, journalists and policy-makers;
- **Supporting innovation and proposal exploitation,** to pave the way for successful exploitation of the Action results, the full range of participants, including academic and private R&D, policy-makers, and end-users will be by incorporated from the beginning, in all WG discussions and other events
- Extended **Networking** to exchange experience with other projects related to the present COST Action, to join efforts, to minimize duplication, and to maximize innovation.

More specifically, the **ROOT-BENEFIT** will develop the following activities:

1) **Scientific and socio-economic actor workshops/meetings**. One general meeting will be organized every year. In addition, two workshops on topics driven by socio-economic actor needs (industry and end-users) will be organized during the Action. Finally, thematic Workshops, whose topics will be defined by WGs, including not only members of academic research but also socio-economic actors and end-users, will be opportunities to discuss innovation concepts for joint development. All meetings/workshops will be organized alternatively on a yearly basis by ITC vs non-ITC countries to promote geographical knowledge transfer. A strict gender balance will be applied both at the level of the organizing committees and for the invited participants giving oral presentations, and YRIs will be prioritized as well. In these events, the results achieved by each WG during the previous periods will be shown. In addition, every participant will have the opportunity to present their ongoing research. The most promising interactions that will emerge from the network in relation to promoting innovation and result exploitation will be selected for discussions in round tables. External well-known researchers will be invited to **ROOT-BENEFIT** events.

2) **Publications.** At least 5 largely collaborative publications in peer-reviewed scientific journals are expected. These articles will deal with general current knowledge on beneficial root-associated microorganism interactions; beneficial root-associated microorganism interactions in relation to sustainable agricultural practices; beneficial root-associated microorganism interactions in relation to climate change; methodologies for studying beneficial root-associated microorganisms; and future research directions in the research field. Moreover, at least one publication in a technical magazine, such as in Phytoma, is expected to promote knowledge transfer into technologies for end-users.

3) **Policy reports.** Consensus or diverging opinions issued from the discussions between industrial, academic, and civil society partners within the different WGs (see below the implementation plan for topic descriptions) will allow proposing new policies, notably in relation to root-associated microorganism inoculant properties and quality controls. Such policy reports will be distributed towards National and European policy-makers.

4) **Websites, media and social media**. Within six months after the initiation of the Action, a functional website will be available where objectives and ongoing activities of **ROOT-BENEFIT** will be published. The website will be regularly updated, including material (e.g. presentations, webinars) that will be accessible to a large public outside the COST Action. A section of the website will be specifically dedicated for the public to promote outreach. Information regarding upcoming meetings and events will be released through a dedicated mailing list and newsletter, National and European Science Academies, and social media such as Twitter and Instagram. A copyright-owner image library, with a target objective of about 200 figures with legends at the end of the Action, will be posted and maintained over the duration of the Action. Updates in the progress of Action activities will be disseminated through dedicated internal and external newsletter mailings and videos posted on YouTube, to target end-users, or through end-user self-organized networks dealing with the use of more sustainable practices, such as “ver de terre production” (www.verdeterreprod.fr) in France. At least one article produced in "The conversation" (www.theconversation.com) will be used as an international communication pipeline to explain to a broad public and journalists the interests of using beneficial root-associated microorganism interactions for more sustainable agriculture. The Action will also develop shared communication tools to be used in outreach events such as the European Researchers’ Night and Fascination of Plants Day, to raise civil society awareness of the relevance of root beneficial interactions towards developing more sustainable agriculture.

4) **Teaching tools**. To reach younger scholars, teaching to Bachelor and Master students by the COST Action participants in their respective Universities will be ensured, using co-created teaching slides shared between **ROOT-BENEFIT** participants. These tools will be submitted to “The Plant Cell teaching tools” (www.academic.oup.com/plcell/pages/teaching-tools-plant-biology) for peer reviewing and to promote a broad dissemination beyond Action participants. Finally, presentations targeted to end-user farmers will be produced by **ROOT-BENEFIT** participants based on each of their respective technological and knowledge expertise, again using co-created outreach slides shared between **ROOT-BENEFIT** participants. If relevant, already existing material at national levels in each of the **ROOT-BENEFIT** member countries will be translated in the official European languages to be shared among the participants.

Table 1. Summary of **ROOT-BENEFIT** activities.

Activities	Year 1	Year 2	Year 3	Year 4	Total number
MC meetings	1*	1*	1*	1*	4*
General meetings	1	1	1	1	1

Working Group Workshops	1 / WG	1 / WG	1 / WG	1 / WG	20
Workshops on non-academic stakeholder-driven topics	1		1		2
STSM call	2	2	2	2	8
Training schools	1	1	1	1	4

* additional online meetings will be organized between an annual physical meeting of the MC.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

WG1: Functional characterization of beneficial microorganism diversity

Advances in sequencing and computational approaches have provided the scientific community with unprecedented insights into the taxonomic composition and encoded functions of the microbial community associated with plants, among which the beneficial root-associated microorganisms are of particular interest for both basic science and translational applications. However, this research field remains essentially "fragmented": individual studies often focus on specific combinations of plants and microorganisms, making it difficult to define common principles regarding the recruitment of the different beneficial microorganisms. This WG will tackle this knowledge gap by retrieving and reanalyzing sequencing data present in the current literature of the plant root microbiota using a common computational framework to focus on services provided by beneficial root-associated microorganisms. This approach will shed new light on the ecological coherence of beneficial microorganisms and identify whether any taxa and functions could be conserved across plant lineages.

The specific objectives of WG1 are:

Objective 1.1. To develop a curated database of sequencing studies describing beneficial root-associated microorganisms.

Objective 1.2. To reconstruct the taxonomic affiliation of plant beneficial root-associated microorganisms across plant lineages.

Objective 1.3. To infer the functional potential of beneficial root-associated microorganisms by interrogating large-scale genomic datasets, and evaluate the efficiency of the services they provide.

These objectives will be achieved by using the following methods and means:

To achieve objective 1.1, the current literature for studies describing beneficial microorganisms will be mined using *ad hoc* search terms. Cut-off dates as well as the following criteria will be included in the survey: a) primary literature (e.g., not review manuscripts), b) quantitative and replicated measurements of a plant growth/health parameters must be present and c) availability of a sequencing dataset. The selected manuscripts will be further classified according to the type of host species (e.g., cereals, legumes, horticultural crops, model species and others), as well as the primary beneficial effects exerted by microorganisms (e.g., growth promotion *per se* and/or pathogen protection). In addition, soil-based and lab-based (axenic) experimental designs will be discriminated. Finally, for each study, the cognate raw sequencing datasets will be retrieved.

For objective 1.2, these raw sequencing data will be processed according to an established pipeline depending on the nature of the primary information (e.g., individual genomes, amplicon survey and metagenomics) in order to create so-called observation/count matrices and implement descriptive statistical approaches to characterise these studies. Using open source tools, the contribution of defined factors, namely host species and types of services will be evaluated, and the distribution of beneficial root-associated microorganisms, their taxonomic affiliations and their encoded functions (the latter for individual genome and metagenomics data) will be investigated.

For objective 1.3, as amplicon sequencing surveys are anticipated to represent a significant proportion of our activity, data gathered from objective 2 will be used to interrogate existing genomic collections of plant-associated microorganisms. The gathered taxonomic information will be used to predict *in silico* metagenomic composition and process obtained data as indicated in the objective 1.2. A focus will be made on barcodes that could allow intragenus/species identification, with the ultimate objective to define markers relevant to evaluate the functional efficacy of the services provided.

WG2: Molecular mechanisms associated with beneficial interaction networks

The objective of WG2 is to define similarities and differences of molecular mechanisms regulating the establishment and functioning of beneficial root-associated microorganism interactions, and cross regulations occurring during complex interactions, and more specifically, to determine how these interactions co-exist, compete or have synergistic effects on plant growth and protection against diseases and abiotic stress. The interaction between expert researchers in the field will allow reviewing the relevant scientific literature, mining databases, and performing meta-analysis studies of published data on different plant species and microorganisms. At first, efforts will be devoted to the two best-known plant beneficial associations (i.e., AM fungi and N-fixing rhizobia), which will then be extended to other beneficial plant- microorganism associations (e.g. plant growth promoting (PGP) bacteria/fungi). These collaborative studies will identify gaps in knowledge and propose future research lines and management strategies for the use of these microorganisms, either individually or in consortia, in agriculture. In addition, a focus will be made on studies related to on-going climate change challenges, to highlight the potential of using beneficial root-associated microorganisms in a context of fast evolving environmental conditions.

The specific objectives of WG2 are:

Objective 2.1. To summarize knowledge on specific and common molecular and cellular mechanisms controlling beneficial root-associated microorganism interactions

Objective 2.2. To provide a comprehensive analysis of the molecular mechanisms that govern and/or are modulated during multiple beneficial root-associated microorganism interactions.

Objective 2.3. To evaluate how these molecular mechanisms are regulated by environmental factors in the frame of agricultural practices and climate change contexts.

These objectives will be achieved by using the following methods and means:

The evolutionary relationship between AM and rhizobial symbioses has revealed that the genetic program of the more ancient mycorrhizal symbiosis was recruited for the rhizobial interaction. To achieve objective 2.1 and 2.2, a literature review will first be performed on genetic factors involved in beneficial root-associated microorganism interactions, both on the plant and on the microbial side. Quantitative parameters will be collected with the aim of using this knowledge to facilitate further comparative studies of complex beneficial root-associated microorganism interactions. The synergistic exchange of knowledge among the different research groups involved in **ROOT-BENEFIT** will be critical to reach these objectives.

To address the objective 2.3, meta-analysis studies will focus on the effect of different agricultural factors, such as fertilization, cropping systems, and soil type, as well as of environmental climate change-related stress factors (high CO_2, drought, temperature, light and radiation), on the formation and functioning of beneficial root-associated microorganism interactions. The impact of these environmental conditions on key molecular mechanisms identified as relevant in the objective 2.1 will be addressed. The knowledge generated in objectives 2.1 and 2.2 will be used to publish focused reviews in peer-reviewed open access journals as a useful resource for researchers, companies and end-users. Target and quantitative parameters identified will fuel the WG3 analyses.

WG3: Ecological and economical services provided by the root beneficial interaction networks

The objective of the WG3 is primarily to establish concepts and frameworks to assess and quantify services provided regarding plant/crop growth, yields and nutritional quality, beneficial root-associated microorganisms, their functional diversity, multi-functionality and synergism/antagonism between the different microorganisms, taking into account their environmental dependency. In coordination with the WG2, the published literature will be used for meta-analyses to propose/quantify ecological and economic values of these beneficial interaction networks, reflecting their contribution towards securing agricultural production base upon stable, changing, or fluctuating climatic conditions, maintenance and improving of ecosystem services and human well-being.

The specific objectives of WG3 are:

Objective 3.1. To provide a comprehensive meta-analysis of benefits (mineral nutrition, abiotic and biotic stress tolerance/resistance, soil, water and air quality) conferred by beneficial

microorganisms/microbiomes, considering the different methodologies and approaches to assess the benefits directly or indirectly (e.g. through molecular proxies).

Objective 3.2. To propose a framework to determine economic value(s) of the benefits, taking into account different aspects such as values for socio-economic actors, including end-users and citizens.

Objective 3.3. To analyse previously published literature for modulation of the services caused by changing environmental conditions, including agricultural management and/or global climate changes.

Objective 3.4. To estimate the potential of beneficial interaction networks to help secure agricultural production based upon stable, changing, or fluctuating climates.

These objectives will be achieved by using the following methods and means:

To address objective 3.1, meta-analyses of the published literature and expert discussions will be conducted in close interaction with WG2 to identify known benefits, their modes of action, and appropriate detection tools, with regards to agro-ecosystem health and resilience.

The objective 3.2 will be tackled mainly by interdisciplinary discussions including ecologists, biologists, sociologists and economists. Furthermore, ideas will be subject to expert scrutiny during a peer review process upon submitting manuscripts to scientific journals.

The objective 3.3 will be mainly achieved by meta-analyses considering studies in both agricultural management contexts and in future climate change scenarios. Direct and indirect (collateral) effects will be considered and available models will be used to allow theoretical predictions of future development upon known environmental and external resource constraints. Results will be confronted to those of the WG2 dealing with symbiotic molecular signals and pathways.

The objective 3.4 will be addressed by using previously generated knowledge, modeling platforms with diversifying possible future scenarios as to changing and/or fluctuating climatic conditions, and/or geopolitical situations affecting external resource (fossil energy, fertilizers, manpower) availability and/or prices.

WG4: Managing and improving beneficial interaction networks under field conditions

The objective of WG4 is to facilitate the implementation of scientifically well-supported strategies for improvement of beneficial root-associated microorganism interactions, as well as the introduction of beneficial root-associated microorganisms in agriculture. Levers for improvement of crop benefits gained from root-associated microorganism interactions are mainly related to crop management, crop breeding, and microbial inoculation. However, beneficial root-associated microorganism interactions are often overlooked in analyses of cropping system performance and in breeding programs. In addition, environmental and agronomical factors explaining the variability of the inoculation impact on crop performance are not well understood. Crop genetic diversity and strain competitiveness are also often not taken into consideration in the process of microorganism selection and evaluation for inoculant production. Finally, there was up to now no effort targeted on the simultaneous co-selection of efficient plants and beneficial root-associated microorganisms. **ROOT-BENEFIT** will identify barriers limiting the implementation of beneficial root-associated microorganisms in agriculture, among which are the stakeholder knowledge and the lack of tools to evaluate crop responses to these microorganisms at the field level. **ROOT-BENEFIT** will also propose recommendations and strategies for inoculant selection and breeding, and methodologies to evaluate their potential in field conditions.

The specific objectives of WG4 are:

Objective 4.1. To identify barriers limiting the use of beneficial root-associated microorganisms under field conditions.

Objective 4.2. To propose recommendations on beneficial root-associated microorganism inoculant properties and quality.

Objective 4.3. To propose methodologies for evaluation of the effect of beneficial root-associated microorganisms in field conditions.

Objective 4.4. To propose strategies for co-selection of plants and microorganisms.

These objectives will be achieved by using the following methods and means:

To address objective 4.1, **ROOT-BENEFIT** participants will study the relevant literature and conduct a survey among plant breeders, agricultural advisers and farmers to collect their input on the state of the art of beneficial root-associated microorganism use, and on key open questions that remain to be addressed for a more widespread application.

The objective 4.2 will be addressed by analysing the literature on the impact of inoculation on the native soil microbiota, as well as on inoculated strain persistence in soils. Criteria for strain selection based on

their competitiveness, persistence and plant response efficacy, will be proposed. Moreover, inoculant quality criteria will be discussed. Finally, evolutions of European and national legislations will be evaluated to provide feedback to policy-makers and end-users. Inoculant producers will be strongly involved of this objective, to take into account not only the scientific relevance, but also economic and practical constraints that may limit the implementation of the proposed strategies and methodologies.

To address the objective 4.3, the knowledge and methodologies identified as relevant in previous WGs will be assessed to determine the potential of their use in large-scale field conditions. Agronomical technical institutes, inoculant producers, breeders and companies proposing soil microbial diagnostics will be specifically integrated for evaluating how realistic could be the implementation of such methodologies in field conditions, taking also into account economical parameters (running costs, equipment needed, etc.)

To address the objective 4.4, plant and microorganism geneticists will propose conceptual strategies for the simultaneous co-selection of adapted and responsive crop and microorganism genotypes. Inoculant producers, breeders will be specifically integrated in this process, to evaluate the feasibility of such approaches. Proof of concept studies will be designed and proposed for funding in future European or translational calls.

The Management Committee (MC) will be in charge of the tasks not covered by the four scientific WGs, including

- Coordination of the different WG activities to stimulate WG interactions;
- Organization of annual meetings;
- Organization of STSM calls;
- Organization of the workshops dedicated to socio-economic actor needs;
- Implementation of the dissemination plan described in 3.2.2
- Writing reports

Regular interactions between the different WGs about work progress will be ensured by the MC. In addition, the MC will ensure the dissemination and secure dataset storage even after the COST Action ends. Finally, the MC will supervise during the whole course of the Action gender, age and geographical balances among participants. The MC will be assisted by executive dissemination, STSM committees and any other leadership roles/committee that will be appointed by the MC.

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

Below are listed the Action deliverables corresponding to the main outcomes of **ROOT-BENEFIT** activities planned in the different WGs, as well as an estimated time frame for completion:

- **D1.1:** A comprehensive meta-analysis of the currently available sequencing information particularly focused on beneficial root-associated microorganisms (Year 2, semester 1, publication).
- **D1.2:** A dataset of microbial taxa and functions associated to beneficial services conserved across plant lineages (Year 3, semester 1, publication).
- **D1.3:** *Ad hoc* computational scripts to integrate, analyse and interpret distinct sequencing datasets (Year 4, semester 1, publication).
- **D2.1:** A comprehensive analysis of the specific and shared molecular mechanisms governing the different beneficial root-associated microorganism interactions (Year 2, semester 1, publication).
- **D2.2:** A comprehensive analysis of molecular mechanisms that control complex multiple beneficial root-associated microorganism interactions (Year 3, semester 1, publication).
- **D2.3:** An evaluation of the impact of agronomical practices and climate change-related environmental conditions on the molecular mechanisms previously identified (Year 4, semester 1, publication).
- **D3.1:** A comprehensive analysis of services conferred to agro-ecosystems by beneficial interaction networks (Year 2, semester 1, publication).
- **D3.3:** Concept and mathematical models allowing predictions of economic benefits under various future scenarios (Year 3, semester 2, publication).
- **D3.4:** An evaluation of beneficial interaction networks in changing and/or fluctuating environment, ecosystem resistance and resilience (Year 4, semester 1, publication).
- **D4.1:** A comprehensive analysis of barriers and key challenges for field use of beneficial root-associated microorganisms (Year 1, semester 2, report).
- **D4.2:** Recommendations on inoculant properties and quality (Year 2, semester 2, report).

- **D4.3:** Standardized methods for evaluation of the effect of beneficial root-associated microorganisms under field conditions (Year 3, semester 1, best practices).
- **D4.4:** Strategies to co-select plants and microorganisms (Year 4, semester 1, guidelines).

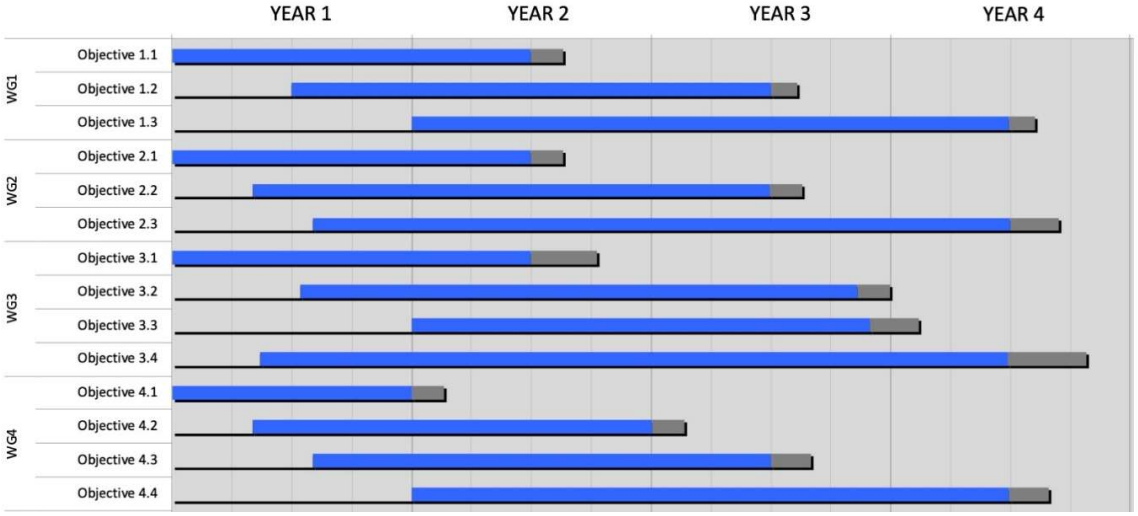
An additional deliverable is

- **D5:** A list of European researchers and laboratories offering expertise and facilities for characterisation of the potential of beneficial root-associated microorganisms (Year 2, semester 1, document).

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

Potential risk	Proposed contingency actions
Difficulties in managing the Action	Clear objectives and roles will be attributed at the beginning of the Action to the WG Leaders (organization of the workshops, meta-analyses, publication writing supervision). Specific tasks will be attributed to the Action members: TS organization, teaching tool production, etc.
Difficulties in ensuring an engagement of all participants	"Online" meetings and 'in person' meetings, when possible, will be organized to coordinate the workload and stimulate the involvement of all **ROOT-BENEFIT** participants, notably those with responsibilities
Difficulties in reaching objectives because of lack of specific skills	Experts will be invited to participate in specific workshops
Little involvement of socio-economic actors	Some representatives of various relevant socio-economic actors have declared their interest in the Action. Additional socio-economic actors will be invited to join the network or specific workshops, to ensure a maximal representativeness of all stakeholders
Activities may overlap with ongoing European initiatives dealing with similar aspects	Past and current related initiatives (COST Actions, H2020 and Horizon Europe projects…) will be listed at the beginning of the Action and updated every year. If overlap occurs, their project leaders will be contacted to reduce redundancy and create synergies based on complementarities
Difficulties to have good participation in workshops and TS	The advertising of **ROOT-BENEFIT** events using social networks and specific channels (dedicated mailing lists, academic societies, conference,…) will be increased to reach a larger audience
Data loss	A data management plan will be established during the first six months of the Action, which will notably ensure data storage along all the Action duration and even after the end of the Action. Data safeguarding will rely on policies / facilities of Action chairperson institutes / companies.

4.1.4. GANTT DIAGRAM



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