# Probiotics in Agroecosystem

Vivek Kumar • Manoj Kumar
Shivesh Sharma • Ram Prasad
Editors

# Probiotics in Agroecosystem

Springer

*Editors*
Vivek Kumar
Himalayan School of Biosciences
Swami Rama Himalayan University
Jolly Grant
Dehradun
Uttarakhand
India

Manoj Kumar
Amity Institute of Microbial Technology
Amity University
Noida
Uttar Pradesh
India

Shivesh Sharma
Department of Biotechnology
Motilal Nehru National Institute
of Technology
Allahabad
Uttar Pradesh
India

Ram Prasad
Amity Institute of Microbial Technology
Amity University
Noida
Uttar Pradesh
India

ISBN 978-981-10-4058-0 ISBN 978-981-10-4059-7 (eBook)
DOI 10.1007/978-981-10-4059-7

Library of Congress Control Number: 2017953188



Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

# Preface

## Probiotics in Agro-Ecosystems

As a general notion, probiotics are beneficial microbes for human health, and are, by definition, living microbes, which when administered appropriately confer a benefit to the host. Advertisements and recent research claim that probiotic products are good for our health, resulting in improved digestion, immunity, and management of allergies and colds. However, the probiotic prospective applications in nondairy-food products and agriculture have not received proper recognition. Presently there is increased interest in food and agricultural applications of probiotics, selection of new probiotic strains, and the development of new applications. The agricultural applications of probiotics with regard to animal, fish, and crop plants have increased steadily, yet a number of uncertainties concerning technological, microbiological, regulatory, and ignored aspects do exist.

Human systems obtain benefits from the beneficial bacteria of probiotics. Likewise, plants also reflect a dependency on certain eco-friendly microbes that act in symbiosis, i.e. plant strengtheners, bioinoculants, phytostimulators, and biopesticides, which eventually benefit human health and agro-ecosystems. The way these microbes are associated with or inhabit plant systems and the fate of their interaction are still poorly understood at a metabolic level. It most likely differs according to microbial plethora, age, and species of the plant, although numerous environmental factors do influence this association.

Scientists have known for decades that legume plants harbor beneficial bacteria in nodules, which fix unavailable nitrogen into a form the plant can easily use. On the other hand, the plant root surface, especially the rhizosphere region, harbors diverse beneficial bacteria and fungi along with various types of endophytes, which are present in the host tissue. This endophytic plant relationship is a matter of adaptation during the process of evolution. Plants have a restricted capacity to genetically adapt to rapidly changing environmental conditions such as temperature, water stress, pathogens, or limited nutrient resources. Therefore, plants may use microbes that have the potential to evolve rapidly owing to their short life cycles and simple genetic material, and help the plant to overcome unfavorable conditions. During the

process of selection, the host plant chooses or favors the right microbes for particular conditions, which helps the plants to be healthier and competitive. In this way, it is comparable to humans taking probiotics to improve their health.

The increasing interest in the preservation of the environment and the health of consumers is demanding change in production methods and food consumption habits. Consumers demand functional foods because they contain bioactive compounds in bioavailable forms that are involved in health protection. To fulfill consumers' demands, plants are inoculated with biofertilizers, which are linked to the roots or move inside them, thus acting as plant probiotics and to some extent they become reliable substitutes for chemical fertilizers.

These beneficial microbes are plant probiotics, which promote plant growth through diverse mechanisms such as phosphate solubilization, nitrogen fixation, phytohormone and siderophore production, and by mitigating abiotic and biotic stress. They act as vector carriers that take up unavailable nutrients, move them through the soil, and mobilize them to the root. This concept posits that less is wasted, whatever is available is utilized, and that less needs to be applied. The plant thrives in an environment of lower pollution, and nutrients taken up by the organisms are not available to be leached into the ground and surface waters. In addition, this concept creates a healthy soil that produces superior and healthy plants and involves much more than using only chemical inputs. Regular application of only synthetic inputs leads to reduced soil quality and fortifies plants with chemicals, which results in unhealthy produce, imparting negative effects on human health.

Health-conscious society has encouraged farmers and organic growers to adopt these microbial-based probiotic technologies to inoculate seeds/soils/roots to provide nutrients like phosphate, nitrogen, and other phytostimulatory compounds. In addition, microorganisms have also attracted worldwide consideration owing to their role in disease management, drought tolerance, and remediation of polluted soils. Accordingly, selected and potentially selected microbial communities are possible tools for sustainable crop production and can set a trend for a healthy future. Scientific researchers draw on multidisciplinary approaches to understanding the complexity and practical utility of a wide spectrum of microbes for the benefit of crops. The success of crop improvement, however, largely depends on the performance of microbes and the willingness and acceptance by growers to cooperate. A substantial amount of research has been carried out to highlight the role of microbes in the improvement of crops, but very little attempt is made to organize such findings in a way that can significantly help students, academics, researchers, and farmers.

"Plant Probiotics in Agro-Ecosystems" is conceptualized by experts providing a broad source of information on strategies and theories of probiotic microbes with sustainable crop improvement in diverse agro-ecosystems. The book presents strategies for nutrient fortification, adaptation of plants in contaminated soils, and mitigating pathogenesis, and explores ways of integrating diverse approaches to accomplish anticipated levels of crop production under outdated and conventional

agro-ecosystems. It is believed that the enthusiasm and noteworthy opportunities presented in this work regarding our recent understanding of the challenges and relationships that bring about learning plant probiotic and synergistic approaches towards plant and human health will inspire readers to push the field forward to new frontiers.

Dehradun, Uttarakhand, India — Vivek Kumar
Noida, Uttar Pradesh, India — Manoj Kumar
Allahabad, Uttar Pradesh, India — Shivesh Sharma
Noida, Uttar Pradesh, India — Ram Prasad

# Contents

# About the Editors

**Vivek Kumar, PhD** is Associate Professor, involved in teaching, research and guidance, with a pledge to enduring knowledge. Dr. Kumar works at Himalayan School of Biosciences, Swami Rama Himalayan University, Dehradun, India. He obtained his Masters and Ph.D degrees from CCS Haryana Agricultural University, Hisar, Haryana, India. He serves as an editor and reviewer of several reputed international journals. He has published 61 research papers, 30 book chapters, six review articles, and four books. Dr. Kumar has also served as a microbiologist for 8 years in the Department of Soil and Water Research, Public Authority of Agricultural Affairs and Fish Resources, Kuwait. He has been credited with first-time reporting and identification of pink rot inflorescence disease of the date palm in Kuwait caused by *Serratia marcescens*. He has also organized a number of conferences/workshops as convener/organizing secretary.

Dr. Kumar's research areas are plant-microbe-interactions, environmental microbiology, and bioremediation. He was awarded the 'Young Scientist Award' for the year 2002 in 'Agricultural Microbiology' by the Association of Microbiologists of India (AMI).

**Manoj Kumar, PhD** is a positive-minded scientist who has a passion for research and development, with a commitment to lifelong learning. He is devoted to high quality science that contributes broadly to both increasing the intellectual knowledge of plant development and to increasing the ecological niche. He has a high level of professional desire and intellectual curiosity, and the potential to fulfil the dream of his high impact publications and the future recognition of these by academic peers.

Dr. Kumar completed his PhD in plant biotechnology at the prestigious Jawaharlal Nehru University and was then awarded two post-doctoral fellowships consecutively: i) DBT-PDF from IISc Bangalore in 2005 and then NRF-PDF from University of Pretoria.

Dr. Manoj Kumar is a researcher of plant biotechnology in the Amity University Uttar Pradesh, India. His present research goal is to understand the metabolic fate of microbial-mediated precursors in whole plant physiology and genetics through processes occurring at the level of metabolism, particularly through processes of

rhizosphere communication under *in situ* and *in vitro* plant conditions. Many graduate and undergraduate students who have worked with him have been placed in prestigious organizations worldwide.

Dr. Kumar has published his research work in many prestigious journals and played the role of reviewer for many of his peers.

**Shivesh Sharma, PhD** is Associate Professor and Head of the Department of Biotechnology at Motilal Nehru National Institute of Technology (MNNIT), Allahabad, Uttar Pradesh, India. Dr. Shivesh Sharma has completed his Masters and Ph.D. in the field of Microbiology. His research interests include environmental microbiology/biotechnology, plant-microbe interaction and bioformulations. Before joining MNNIT Allahabad, Dr. Shivesh Sharma worked at S.B.S (PG) Institute of Biomedical Sciences and Research, Balawala, Dehradun Uttarakhand from 2002–2009. He has been involved in a number of research projects funded both externally (DBT, UGC, DST, MHRD) and internally in the fields of his research interests. His teaching interests include microbiology, environmental microbiology/biotechnology, food biotechnology, bacteriology, and IPR.

He has successfully supervised seven Ph.D., eight M. Tech. and 28 M.Sc. students. He has more than 80 publications in different research journals and various book chapters to his credit. He has also organized various outreach activities.

**Ram Prasad, PhD** is Assistant Professor at the Amity University, Uttar Pradesh, India. Dr. Prasad completed his Ph.D. from the Department of Microbiology, Chaudhary Charan Singh University, Meerut, UP, India, in collaboration with the School of Life Sciences, Jawaharlal Nehru University (JNU), New Delhi, India. Dr. Prasad received his M.Sc. in Life Sciences at JNU and also qualified CSIR-NET, ASRB-NET, and GATE. His research interest includes plant-microbe interactions, sustainable agriculture, and microbial nanobiotechnology. Dr. Prasad has 93 publications to his credit including research papers and book chapters, five patents issued or pending, and has edited or authored several books. Dr. Prasad has 11 years of teaching experience and he has been awarded the Young Scientist Award (2007) and Prof. J.S. Datta Munshi Gold Medal (2009) by the International Society for Ecological Communications; FSAB fellowship (2010) by the Society for Applied Biotechnology; Outstanding Scientist Award (2015) in the field of Microbiology by Venus International Foundation, and the American Cancer Society UICC International Fellowship for Beginning Investigators (USA, 2014). In 2014–2015, Dr. Prasad served as Visiting Assistant Professor in the Department of Mechanical Engineering at Johns Hopkins University, USA.

# Contributors

**Saida Aarab** Département de Biologie, Faculté des Sciences et Techniques d'Al Hoceima, Al Hoceima, Morocco

Equipe de Recherche de Biotechnologies et Génie des Biomolécules (ERBGB), Faculté des Sciences et Techniques de Tangier, Tangier, Morocco

**Adebayo Adeyemo** Department of Crop, Soil and Pest Management, Federal University of Technology, Akungba-Akoko, Ondo State, Nigeria

Department of Agronomy, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

**Ees Ahmad** Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Iqbal Ahmad** Department of Agricultural Microbiology, Aligarh Muslim University, Aligarh, India

**Shafaqat Ali** Department of Environmental Sciences and Engineering, Government College University, Faisalabad, Pakistan

**Mohd Musheer Altaf** Department of Agricultural Microbiology, Aligarh Muslim University, Aligarh, India

**Abdullah Safar Al-Thubiani** Department of Biology, Umm Al-Qura University, Makkah, Saudi Arabia

**Rizwan Ali Ansari** Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Abdelhay Arakrak** Equipe de Recherche de Biotechnologies et Génie des Biomolécules (ERBGB), Faculté des Sciences et Techniques de Tangier, Tangier, Morocco

**Priyanka Arora** School of Sciences, Noida International University, Greater Noida, India

**Moses Awodun** Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Ondo State, Nigeria

Department of Agronomy, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

**Mohammed Bakkali** Equipe de Recherche de Biotechnologies et Génie des Biomolécules (ERBGB), Faculté des Sciences et Techniques de Tangier, Tangier, Morocco

**Danas Baniulis** Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, Babtai, Lithuania

**Driss Bouhraoua** Equipe de Recherche de Biotechnologies et Génie des Biomolécules (ERBGB), Faculté des Sciences et Techniques de Tangier, Tangier, Morocco

**Lorena Carro** School of Biology, Newcastle University, Tyne, UK

**Deepika Chaudhary** Department of Microbiology, CCS Haryana Agricultural University Hisar, Haryana, India

**Kumud Dubey** Centre for Social Forestry and Eco-Rehabilitation, Allahabad, Uttar Pradesh, India

**K.P. Dubey** CCF/General Manager, (East), Uttar Pradesh Forest Corporation Allahabad, Allahabad, Uttar Pradesh, India

**Renato Fernandes Galdiano Júnior** Department of Technology, State Paulista University – UNESP, São Paulo, Brazil

**Paula García-Fraile** Institute of Microbiology of the CAS, v. v. i, Vestec, Czech Republic

**Satwant Kaur Gosal** Department of Microbiology, Punjab Agricultural University, Ludhiana, India

**Zaid ul Hassan** Department of Environmental Sciences and Engineering, Government College University, Faisalabad, Pakistan

**Muhammad Ibrahim** Department of Environmental Sciences and Engineering, Government College University, Faisalabad, Pakistan

**Rosangela Naomi Inui Kishi** Department of Technology, State Paulista University – UNESP, São Paulo, Brazil

**Veluswamy Karthikeyan** Centre for Research, Department of Botany and Biotechnology, Thiagarajar College, Madurai, Tamil Nadu, India

**Jupinder Kaur** Department of Microbiology, Punjab Agricultural University, Ludhiana, India

**Mohd Saghir Khan** Department of Agricultural Microbiology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Mohammad Saghir Khan** Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Luciano Takeshi Kishi** Department of Technology, State Paulista University – UNESP, São Paulo, Brazil

**Martin Kostovčík** Institute of Microbiology of the CAS, v. v. i, Vestec, Czech Republic

**Manoj Kumar** Amity Institute of Microbial Technology, Amity University, Noida, Uttar Pradesh, India

**Nitin Kumar** Department of Biotechnology, Motilal Nehru National Institute of Technology Allahabad, Allahabad, Uttar Pradesh, India

**Rakesh Kumar** Department of Microbiology, CCS Haryana Agricultural University Hisar, Hisar, Haryana, India

**Vivek Kumar** Himalayan School of Biosciences, Swami Rama Himalayan University, Jolly Grant, Dehradun, Uttarakhand, India

**Anju Kumari** Centre of Food Science and Technology CCS Haryana Agricultural University Hisar, Hisar, Haryana, India

**Amin Laglaoui** Equipe de Recherche de Biotechnologies et Génie des Biomolécules (ERBGB), Faculté des Sciences et Techniques de Tangier, Tangier, Morocco

**Salvador Lladó** Institute of Microbiology of the CAS, v. v. i, Prague, Czech Republic

**Rafiq A. Lone** School of Studies in Botany, Jiwaji University, Gwalior, Madhya Pradesh, India

Department of Natural Sciences, SBBS University, Khiala (Padhiana), Jalandhar, Punjab, India

**Rubén López-Mondéjar** Institute of Microbiology of the CAS, v. v. i, Vestec, Czech Republic

**Mamta** Department of Environmental Science, Jiwaji University, Gwalior, Madhya Pradesh, India

**Irshad Mahmood** Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Manuel Megias** Departamento de Microbiología y Parasitología, Facultad de Farmacia, Universidad de Sevilla, Sevilla, Spain

**Inga Tamosiune** Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, Babtai, Lithuania

**M. Miransari** Department of Book & Article, AbtinBerkeh Scientific Ltd. Company, Isfahan, Iran

**Rohit Mishra** Centre for Medical Diagnostic and Research MNNIT, Allahabad, Uttar Pradesh, India

**Átila Francisco Mógor** Federal University of Paraná, Department of Plant Science and Crop Protection, Curitiba, Paraná, Brazil

**S. Muthulakshmi** P.G and Research Centre, Department of Botany, Thiagarajar College, Madurai, Tamil Nadu, India

**Muhammad Nafees** Institute of Soil & Environmental Sciences. University of Agriculture Faisalabad, Faisalabad, Pakistan

**Segun Oladele** Department of Crop, Soil and Pest Management, Federal University of Technology, Akungba-Akoko, Ondo State, Nigeria

Department of Agronomy, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

**Francisco Javier Ollero** Departamento de Microbiología, Facultad de Biología, Universidad de Sevilla, Sevilla, Spain

**Alok Pandey** Centre for Social Forestry and Eco-Rehabilitation, Allahabad, Uttar Pradesh, India

**Ram Prasad** Amity Institute of Microbial Technology, Amity University, Noida, Uttar Pradesh, India

**Kuppu Rajendran** Center for Research, Department of Botany and Biotechnology, Thiagarajar College, Madurai, Tamil Nadu, India

**Raman Jangra** Department of Microbiology, CCS Haryana Agricultural University Hisar, Haryana, India

**Rashmi** Department of Microbiology, CCS Haryana Agricultural University Hisar, Haryana, India

**Asfa Rizvi** Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Rose Rizvi** Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Muhammad Rizwan** Department of Environmental Sciences and Engineering, Government College University, Faisalabad, Pakistan

**B. Sadhana** P.G and Research Centre, Department of Botany, Thiagarajar College, Madurai, Tamil Nadu, India

**Safiuddin** Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Saima Saif** Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Kulliyan Sathiyadash** Center for Research, Department of Botany and Biotechnology, Thiagarajar College, Madurai, Tamil Nadu, India

**Seema B. Sharma** Department of Earth and Environmental Science, KSKV Kachchh University, Gujarat, India

**Shivesh Sharma** Department of Biotechnology, Motilal Nehru National Institute of Technology, Allahabad, Uttar Pradesh, India

Centre for Medical Diagnostic and Research MNNIT, Allahabad, Uttar Pradesh, India

**Razia Shuab** School of Studies in Botany, Jiwaji University, Gwalior, Madhya Pradesh, India

**Khushboo V. Singh** Department of Microbiology, Gujarat University, Ahmedabad, Gujarat, India

**Vidmantas Stanys** Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, Babtai, Lithuania

**Aisha Sumbul** Section of Plant Pathology and Nematology, Department of Botany, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Vivian Jaskiw Szilagyi Zecchin** Federal University of Paraná, Department of Plant Science and Crop Protection, Curitiba, Paraná, Brazil

**Priyanku Teotia** Department of Botany, CCS University, Meerut, India

**Nitika Thakur** Shoolini University of Biotechnology and Management Sciences, Solan, HP, India

**Archana Tiwari** School of Sciences, Noida International University, Greater Noida, India

**Praveen Tripathi** Centre for Social Forestry and Eco-Rehabilitation, Allahabad, Uttar Pradesh, India

**Neha Upadhyay** Department of Biotechnology, Motilal Nehru National Institute of Technology Allahabad, Allahabad, Uttar Pradesh, India

**Silvana Pompéia Val-Moraes** Department of Technology, State Paulista University – UNESP, São Paulo, Brazil

**Sunita J. Varjani** School of Biological Sciences and Biotechnology, University and Institute of Advanced Research, Gandhinagar, Gujarat, India

**Rishi Kumar Verma** Department of Biotechnology, Motilal Nehru National Institute of Technology Allahabad, Allahabad, Uttar Pradesh, India

**Kanchan Vishwakarma** Department of Biotechnology, Motilal Nehru National Institute of Technology Allahabad, Allahabad, Uttar Pradesh, India

**Khursheed Ahmad Wani** Department of Environmental Science, ITM University, Gwalior, Madhya Pradesh, India

**Muhammad Waseem** Department of Microbiology, Government College University, Faisalabad, Pakistan

**Gaurav Yadav** Department of Biotechnology, Motilal Nehru National Institute of Technology Allahabad, Allahabad, Uttar Pradesh, India

Centre for Medical Diagnostic and Research MNNIT, Allahabad, Uttar Pradesh, India

**Almas Zaidi** Department of Agricultural Microbiology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

**Mohammad Javad Zarea** Faculty of Agriculture, University of Ilam, Ilam, Iran

Faculty of Agriculture, University of Kurdistan, Sanandaj, Iran