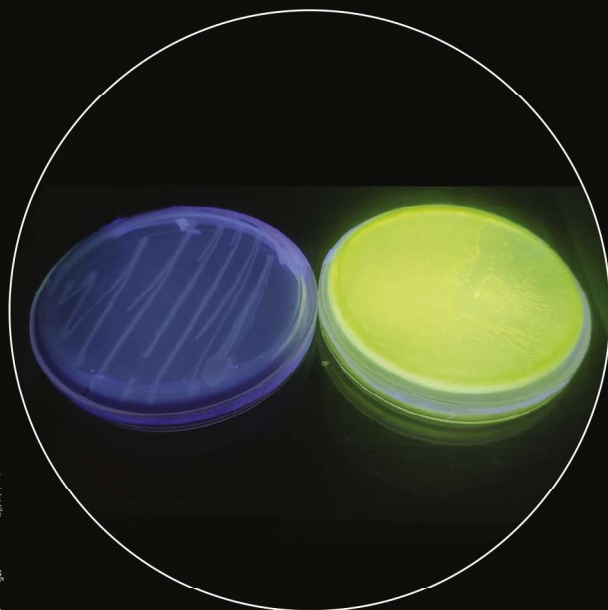


New and Future Developments in Microbial Biotechnology and Bioengineering

Sustainable Agriculture: Microorganisms
as Biostimulants



Edited by
Harikesh Bahadur Singh
Anukool Vaishnav



NEW AND FUTURE DEVELOPMENTS IN MICROBIAL BIOTECHNOLOGY AND BIOENGINEERING

Sustainable Agriculture:
Microorganisms as Biostimulants

Edited by

HARIKESH BAHADUR SINGH

Department of Biotechnology, GLA University, Mathura, India

ANUKOOL VAISHNAV

*Department of Biotechnology, GLA University, Mathura, India; Agroecology and Environment,
Agroscope, Zürich, Switzerland*



ELSEVIER

Elsevier

Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States

Copyright © 2022 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

ISBN: 978-0-323-85163-3

For Information on all Elsevier publications visit our website at
<https://www.elsevier.com/books-and-journals>

Publisher: Susan Dennis

Acquisitions Editor: Susan Dennis

Editorial Project Manager: Regine A. Gandullas

Production Project Manager: Bharatwaj Varatharajan

Cover Designer: Greg Harris

Typeset by Aptara, New Delhi, India



Contents

Contributors ix
About the Editors xiii
Preface xv

1. Role of microorganism as new generation plant bio-stimulants: An assessment

Deepali Shukla, Piyush Shukla, Ashmita Tandon,
Poonam C. Singh, Jayandra Kumar Johri

- 1.1 Background 1
- 1.2 Introduction of plant bio-stimulants 2
- 1.3 Basic mechanism of bio-stimulants 2
- 1.4 Sources of plant bio-stimulants 2
- 1.5 Microbes as plant bio-stimulant 3
- 1.6 Role of microbes in nutrient uptake/ stimulation 8
- 1.7 Conclusions 9
- References 10

2. Exploiting biostimulant properties of *Trichoderma* for sustainable plant production

Ramón Pelagio-Flores, Sarai Esparza-Reynoso, Jesús Salvador López-Bucio, José López-Bucio

- 2.1 Introduction 17
- 2.2 *Trichoderma* metabolism: from decomposers to plant growth promoters 19
- 2.3 *Trichoderma*-plant chemical dialogue 19
- 2.4 *Trichoderma*-induced resistance to plant pathogens 20
- 2.5 *Trichoderma* and plant nutrition 22
- 2.6 Soil acidification in *Trichoderma*-plant interactions 25
- 2.7 Salt stress tolerance mediated by *Trichoderma* 25
- 2.8 Conclusions and future prospects 26
- References 27

3. *Bacillus* rhizobacteria: A versatile biostimulant for sustainable agriculture

S.R. Prabhukarthikeyan, U. Keerthana, Mathew S Baite,
P. Panneerselvam, Debasis Mitra, R. Naveen Kumar,
C. Parameswaran, B. Cayalvizhi, A. Muthu Kumar,
S. Harish, P.C. Rath

- 3.1 Introduction 33
- 3.2 Diversity of *Bacillus* species 34
- 3.3 Direct mechanism of plant growth promotion 35
- 3.4 Indirect mechanism 37
- 3.5 Future prospects 40
- References 40

4. Arbuscular mycorrhizae, a treasured symbiont to agriculture

Ajay Nair, Archana S. Rao, L. Bhanu, Veena S. More,
K.S. Anantharaju, Sunil S. More

- 4.1 Introduction to mycorrhiza 45
- 4.2 VAM in agriculture 48
- 4.3 Application of AMF in bioremediation 55
- 4.4 Renaturation and afforestation 56
- 4.5 Mass production of VAM: the past, present and future 57
- 4.6 Conclusion 59
- References 59

5. Micro and macroalgae: A potential biostimulant for abiotic stress management and crop production

P. Kiruthika Lakshmi, S. Meenakshi

- 5.1 Introduction 63
- 5.2 Review of literature and recent developments 64
- 5.3 Conclusion and future prospects 76
- References 77

Micro and macroalgae: A potential biostimulant for abiotic stress management and crop production

P. Kiruthika Lakshmi^a, S. Meenakshi^b

^aDepartment of Microbiology, The Madura College, Madurai, Tamil Nadu, India, ^bVMJ School, Madurai, Tamil Nadu, India

5.1 Introduction

Increase in global demand for crop production insists on the need for finding sustainable technique to meet the ever-growing nutritional requirement as well as to overcome the stress induced by the agrochemicals. Moreover, resistance of the pests to commercially available agrochemicals like fungicides and herbicides made them ineffective and necessitates the importance of finding alternate strategy for protecting plants (Russell, 2005). Being environmentally, ecologically safe and non-toxic in nature, organic biostimulants and biofertilizers including algal biostimulants are highly preferred for agriculture and plant management programme.

Global demand for food, utilization of crops for biofuel extraction has also increased the cost of chemical fertilizers drastically (FAO 2011). The usage of chemical fertilizers can be reduced by applying suitable organic biostimulant with plant-growth stimulating potential. Microalgae are attracting the interest of agrochemical industries and farmers, due to their biostimulant and biofertiliser properties. These algae-based biostimulants can also serve as an alternate to overcome the impact of climatic change on crop production and to increase agricultural sustainability (Elarroussia et al., 2016).

Microalgae are endowed with enormous amount of micro and macronutrients which are necessary for the plant growth. It can serve as an efficient biostimulant that improve soil properties, fertility, thereby enhancing nutrient uptake, abiotic stress tolerance, crop growth, productivity, quality and shelf life of the plant products (Rouphael and Colla, 2018). Moreover, they are considered to be cost-effective and eco-friendly alternate to agrochemicals and plant growth regulators (Kawalekar, 2013). These microalgae might be useful to improve agricultural sustainability as they enhance crop productivity with negligible impact on the