

Principles in Plant Microbe Interaction for Sustainable Agriculture

edited by
KALAIVANI NADARAJAH

PENERBIT UNIVERSITI KEBANGSAAN MALAYSIA
BANGI • 2024
www.ukm.my/penerbit

Cetakan Pertama / *First Printing*, 2024
Hak Cipta / *Copyright* Universiti Kebangsaan Malaysia, 2024

Hak cipta terpelihara. Tiada bahagian daripada terbitan ini boleh diterbitkan semula, disimpan untuk pengeluaran atau ditukarkan ke dalam sebarang bentuk atau dengan sebarang alat juga pun, sama ada dengan cara elektronik, gambar serta rakaman dan sebagainya tanpa kebenaran bertulis daripada Penerbit UKM terlebih dahulu.

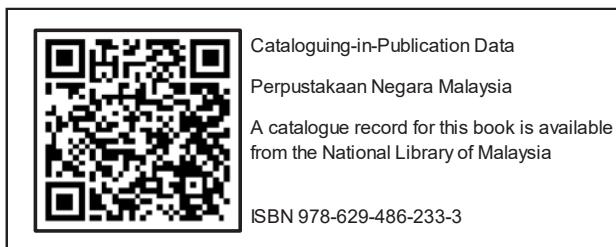
All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopy, recording, or any information storage and retrieval system, without permission in writing from Penerbit UKM.

Diterbitkan di Malaysia oleh / *Published in Malaysia by*
PENERBIT UNIVERSITI KEBANGSAAN MALAYSIA
43600 UKM Bangi, Selangor Darul Ehsan, MALAYSIA
www.ukm.my/penerbit
e-mel: penerbit@ukm.edu.my

Penerbit UKM adalah anggota / *is a member of the*
MAJLIS PENERBITAN ILMIAH MALAYSIA /
MALAYSIAN SCHOLARLY PUBLISHING COUNCIL
PERSATUAN PENERBIT BUKU MALAYSIA /
MALAYSIAN BOOK PUBLISHERS ASSOCIATION
No. Ahli / *Membership No.* 198302

Atur huruf oleh / *Typeset by*
PENERBIT UNIVERSITI KEBANGSAAN MALAYSIA
43600 UKM Bangi, Selangor Darul Ehsan, MALAYSIA

Dicetak di Malaysia oleh / *Printed in Malaysia by*
PEWARIS GEMILANG SDN. BHD.
No. 27G, Jalan Putra 8, Taman Kajang Putra,
43000 Kajang, Selangor Darul Ehsan, MALAYSIA



Contents

List of Tables & Figures ... 7

Preface ... 11

CHAPTER 1 Sustainable Agriculture: The Role of Plant Microbe
Interactions ... 15
Kalaivani Nadarajah

CHAPTER 2 Plant Microbe Interactions in the Rhizosphere ... 24
*Abdul Munir Abdul Murad, Emmyrafedziawati Aida
Kamal Rafedzi & Jonathan Guyang Ling*

CHAPTER 3 Plant Microbe Interactions in the Phyllosphere ... 39
Abdul Munir Abdul Murad & Jonathan Guyang Ling

CHAPTER 4 Non-pathogenic Interactions between Plants
and Microbes ... 53
Izwan Bharudin & Anis Farhan Fatimi Ab Wahab

CHAPTER 5 Pathogenic Interactions between Plants and
Microbes ... 62
Izwan Bharudin & Anis Farhan Fatimi Ab Wahab

CHAPTER 6 Plant Defense Mechanisms: Physical and Biochemical
Defenses ... 73
Nurulhikma Md. Isa

6 / *Principles in Plant Microbe Interaction for Sustainable Agriculture*

CHAPTER 7 Unravelling the Signaling Mechanism in Microbe Triggered Immunity ... 86

Kalaivani Nadarajah

CHAPTER 8 Unravelling the Signaling Mechanism in Elicitor Triggered Immunity ... 98

Kalaivani Nadarajah

CHAPTER 9 Plant Beneficial Microbes in Agriculture ... 120

Kalaivani Nadarajah

CHAPTER 10 Microbiome Engineering for Agriculture ... 137

Kalaivani Nadarajah

CHAPTER 11 Transgenics for Plant Resistance ... 151

Nurulhikma Md. Isa

CHAPTER 12 Breeding for Resistance to Diseases Using Marker-Assisted Selection and QTL Approach ... 161

Mohd Ikmal Asmuni, Siti Nurfaeiza Abd Razak & Noraziyah Abd Aziz Shamsudin

CHAPTER 13 Breeding Plant Biotic Resistance through Genome

Editing ... 175

Kalaivani Nadarajah

References ... 193

List of Contributors ... 249

Index ... 251

FIGURE 11.2 The binary cloning vector has a broad-host-range *ori*, selectable marker genes for *E. coli* and *A. tumefaciens*, and a target gene with a plant selectable marker gene between the T-DNA borders ... 154

FIGURE 11.3 Gene silencing process by RNA interference (RNAi) ... 159

FIGURE 12.1 PGRFA for breeding purposes ... 162

FIGURE 12.2 Development of the F_2 population for QTL mapping ... 164

FIGURE 12.3 General procedure for mapping QTL ... 165

FIGURE 12.4 Steps in conducting GWAS for mapping QTL ... 167

FIGURE 12.5 Crossing scheme for development of recombinant and backcross inbred lines ... 170

FIGURE 12.6 Crossing scheme for development of near isogenic lines ... 171

FIGURE 12.7 Crossing scheme for the development of MAGIC population ... 173

FIGURE 13.1 This schematic illustrates genome editing using CRISPR/Cas9 and Base Editors, which have successfully edited bases, genes, or loci in various plant systems ... 182

Preface

Comprehending the complex interactions between microbes and plants has become essential in the pursuit of sustainable agricultural practices. In-depth examination of concepts, application and possible benefits that come from understanding and applying the knowledge garnered in plant microbe interaction is crucial for the future of sustainable agriculture. A plethora of complex chemical, cellular, and ecological interactions have been revealed as our understanding of the beneficial and non-beneficial relationships between plants and microbes has grown dramatically in recent decades. The interdisciplinary nature of this book emphasizes the interconnectedness of biology, genetics, ecology, and agronomy in the study of plant microbe interactions. This book aims to close the knowledge gap between basic science and real-world application by offering a thorough and comprehensive guide for all readers by combining theoretical underpinnings, experimental techniques, and practical applications. This book will appeal to scientists, students and readers interested in understanding the role microbes in agriculture. The content of the book is provided in brief below.

The journey begins with Chapter 1, delving into the fundamental Principles in Plant-Microbe Interaction for Sustainable Agriculture. It sets the stage for subsequent chapters, providing a solid theoretical foundation for readers from various backgrounds, whether researchers, students, or practitioners.

Chapters 2 and 3 navigate the microcosms of the Rhizosphere and Phyllosphere, respectively, unraveling the unique dynamics of plant-microbe interactions in these critical niches. These insights pave the way for a nuanced understanding of the ecological intricacies that influence plant health and growth.

Moving beyond the dichotomy of pathogenic and non-pathogenic interactions, Chapters 4 and 5 explore the myriad of ways in which plants and microbes collaborate or engage in conflict. Non-pathogenic interactions offer promising avenues for sustainable agriculture, while pathogenic interactions underscore the challenges that must be overcome to ensure crop health and productivity.

Chapter 6 zooms in on Plant Defense Mechanisms, deciphering the physical and biochemical strategies plants employ to ward off microbial threats. Chapters 7 and 8 unravel the intricate Signaling Mechanisms in Microbe Triggered Immunity and Elicitor Triggered Immunity, shedding light on the molecular dialogues that govern plant responses to microbial challenges.

Chapters 9 and 10 shift the focus to the positive sides of the interaction spectrum, exploring the potential of Plant Beneficial Microbes and Microbiome Engineering for Agriculture. These chapters showcase how harnessing the power of beneficial microbes can enhance plant growth, nutrient uptake, and overall resilience.

The latter portion of this book explores cutting-edge approaches to enhancing plant resistance. Chapters 11, 12, and 13 delve into Transgenics for Plant Resistance, Breeding for Tolerance to Diseases using Marker-assisted Selection and QTL Approach, and Breeding Plant Biotic Resistance Through Genome Editing, respectively. These chapters showcase the evolving landscape of biotechnological interventions aimed at creating crops with enhanced resistance to pests and diseases.

As we navigate these chapters, we hope readers will find inspiration, knowledge, and practical insights to contribute to the ongoing revolution in sustainable agriculture.

The authors would like to thank Universiti Kebangsaan Malaysia for the use of the research facilities within UKM. We would also like to acknowledge funding agencies for their support of the work reported in this book. Chapters 2 and 3 of this book are supported by Ministry of Higher Education, Fundamental Research Grant Scheme FRGS/1/2019/STG03/UKM/02/2. Chapters 4 and 5 are supported by Ministry of Higher Education's, Fundamental Research Grant Scheme FRGS/1/2020/STG03/UKM/02/1, and Universiti Kebangsaan Malaysia's DIP-2019-022, GGPM-2017-071 and GUP-2022-044. Chapters 7 and 8 are supported by ESciencefund MOSTI 02-01-02-SF0139, 02-01-02-SF0757, and 02-01-02-SF1232. While Chapters 9, 10 and 13 are supported by Ministry of Higher Education's, Fundamental Research Grant Scheme FRGS/1/2023/STG01/UKM/01/1 and FRGS/1/2019/STG03/UKM/01/2. Chapter 11 is supported under Ministry of Higher Education's, Fundamental Research Grant Scheme FRGS/1/2020/STG01/UKM/02/6. Lastly, Chapter 12 is supported under UKM's Internal Research Grant GGPM-2022-034. In

addition, we thank Jonathan Guyang Ling for his assistance in compiling the book. The authors would also like to thank *Jurnal Sains Malaysiana* for their support of this publication.

Kalaivani Nadarajah