

Physiological Responses and Genetic Improvement for Stress Resistance



<sub>Editors:</sub> Phetole Mangena Sifau A. Adejumo

**Bentham Books** 

# Advances in Legume Research: Physiological Responses and Genetic Improvement for Stress Resistance

# (Volume 2)

Edited by

# **Phetole Mangena**

Department of Biodiversity School of Molecular and Life Sciences Faculty of Science and Agriculture University of Limpopo, Limpopo Province Republic of South Africa

k

# Sifau A. Adejumo

Department of Crop Protection and Environmental Biology Faculty of Agriculture University of Ibadan, Ibadan, Nigeria

#### Advances in Legume Research: Physiological Responses and Genetic Improvement for Stress Resistance

(Volume 2)

Editors: Phetole Mangena & Sifau A. Adejumo

ISSN (Online): 2737-4890

ISSN (Print): 2737-4882

ISBN (Online): 978-981-5165-31-9

ISBN (Print): 978-981-5165-32-6

ISBN (Paperback): 978-981-5165-33-3

©2023, Bentham Books imprint.

Published by Bentham Science Publishers Pte. Ltd. Singapore. All Rights Reserved.

First published in 2023.

#### BENTHAM SCIENCE PUBLISHERS LTD.

#### End User License Agreement (for non-institutional, personal use)

This is an agreement between you and Bentham Science Publishers Ltd. Please read this License Agreement carefully before using the book/echapter/ejournal (**"Work"**). Your use of the Work constitutes your agreement to the terms and conditions set forth in this License Agreement. If you do not agree to these terms and conditions then you should not use the Work.

Bentham Science Publishers agrees to grant you a non-exclusive, non-transferable limited license to use the Work subject to and in accordance with the following terms and conditions. This License Agreement is for non-library, personal use only. For a library / institutional / multi user license in respect of the Work, please contact: permission@benthamscience.net.

#### **Usage Rules:**

- 1. All rights reserved: The Work is the subject of copyright and Bentham Science Publishers either owns the Work (and the copyright in it) or is licensed to distribute the Work. You shall not copy, reproduce, modify, remove, delete, augment, add to, publish, transmit, sell, resell, create derivative works from, or in any way exploit the Work or make the Work available for others to do any of the same, in any form or by any means, in whole or in part, in each case without the prior written permission of Bentham Science Publishers, unless stated otherwise in this License Agreement.
- 2. You may download a copy of the Work on one occasion to one personal computer (including tablet, laptop, desktop, or other such devices). You may make one back-up copy of the Work to avoid losing it.
- 3. The unauthorised use or distribution of copyrighted or other proprietary content is illegal and could subject you to liability for substantial money damages. You will be liable for any damage resulting from your misuse of the Work or any violation of this License Agreement, including any infringement by you of copyrights or proprietary rights.

#### **Disclaimer:**

Bentham Science Publishers does not guarantee that the information in the Work is error-free, or warrant that it will meet your requirements or that access to the Work will be uninterrupted or error-free. The Work is provided "as is" without warranty of any kind, either express or implied or statutory, including, without limitation, implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the results and performance of the Work is assumed by you. No responsibility is assumed by Bentham Science Publishers, its staff, editors and/or authors 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 instruction, advertisements or ideas contained in the Work.

#### Limitation of Liability:

In no event will Bentham Science Publishers, its staff, editors and/or authors, be liable for any damages, including, without limitation, special, incidental and/or consequential damages and/or damages for lost data and/or profits arising out of (whether directly or indirectly) the use or inability to use the Work. The entire liability of Bentham Science Publishers shall be limited to the amount actually paid by you for the Work.

#### General:

2. Your rights under this License Agreement will automatically terminate without notice and without the

<sup>1.</sup> Any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims) will be governed by and construed in accordance with the laws of Singapore. Each party agrees that the courts of the state of Singapore shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims).

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd. 80 Robinson Road #02-00 Singapore 068898 Singapore Email: subscriptions@benthamscience.net



#### CONTENTS

FOREWORD	i
PREFACE	ii
ACKNOWLEDGEMENT	iii
LIST OF CONTRIBUTORS	iv
CHAPTER 1 BIOTIC STRESS AND BREEDING OF PLANTS FOR STRESS RESISTANCE Phetole Mangena and Sifau A. Adejumo DEFINING BIOTIC STRESS INSECT PESTS MICROPIAL PATHOCENS	1 2 4
WEED PLANTS	7
BREEDING FOR BIOTIC STRESS RESISTANCE CONCLUDING REMARKS LIST OF ABBREVIATIONS CONSENT FOR PUBLICATION CONFLICT OF INTEREST ACKNOWLEDGEMENT REFERENCES	8 9 10 11 11 11 11
CHAPTER 2 CURRENT KNOWLEDGE ON BIOTIC STRESSES AFFECTING LEGUMES: DEDSDECTIVES IN COWDEA AND SOUDEAN	14
PERSPECTIVES IN COWPEA AND SOYBEAN	14
INTRODUCTION	14
BIOTIC STRESSES IN LEGUMES	15
COWPEA	16
SOYBEAN	17
BIOTIC CONSTRAINTS TO COWPEA AND SOYBEAN PRODUCTION	19
Fungal Diseases	
Fusarium Wilt	19
Anthracnose Rlight	20
Cownea/Sovhean Rust	21
Bacterial Diseases	22
Leaf Rlight	22
Viral Diseases	24
Weeds	26
Insect Pests of Cowpea and Sovbean	26
Nematode Pests of Cowpea and Sovbean	28
CONCLUSION	
LIST OF ABBREVIATIONS	
CONSENT FOR PUBLICATION	30
CONFLICT OF INTEREST	
ACKNOWLEDGEMENT	30
REFERENCES	
CHAPTER 3 INDEXING FOR BACTERIAL, FUNGAL AND VIRAL PATHOGENS IN	27
LEGUME FLANIS	31
rnumzue Mknize, Josephine Malaiji and Phetole Mangena	27
	3/
INDEAING APPKUACHES	39

Mold and Fungal Phylogenic Characteristics       42         Viral and Bacterial Phylogeny and Characteristics       43 <b>DIAGNOSTIC METHODS FOR MICROBIAL PLANT PATHOGENS</b> 44         PCR-Based Detection       45         PCR-SSCP and Competitive PCR       46         Serological Methods of Pathogen Detection       46         Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48
Viral and Bacterial Phylogeny and Characteristics       43         DIAGNOSTIC METHODS FOR MICROBIAL PLANT PATHOGENS       44         PCR-Based Detection       45         PCR-SSCP and Competitive PCR       46         Serological Methods of Pathogen Detection       46         Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48
DIAGNOSTIC METHODS FOR MICROBIAL PLANT PATHOGENS       44         PCR-Based Detection       45         PCR-SSCP and Competitive PCR       46         Serological Methods of Pathogen Detection       46         Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48
PCR-Based Detection       45         PCR-SSCP and Competitive PCR       46         Serological Methods of Pathogen Detection       46         Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48
PCR-SSCP and Competitive PCR       46         Serological Methods of Pathogen Detection       46         Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48         EULUPUE       48
Serological Methods of Pathogen Detection
Multiplexing Real Time PCR       47         Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48         FUTURE PROSENCTS       47
Next Generation Sequencing (NGS)       47         BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL       48         FUTURE PROSPECTS       48
BIOLOGICAL AND CHEMICAL PLANT DISEASE CONTROL
FUTURE PROSPECTS
CONCLUDING REMARKS
LIST OF ABBREVIATIONS
CONSENT FOR PUBLICATION
CONFLICT OF INTEREST
ACKNOWLEDGEMENT
<b>REFERENCES</b>
CHARTER 4 MIDAL DISEASES OF LECTIMES AND THEID MANACEMENTS
CHAPTER 4 VIKAL DISEASES OF LEGUMES AND THEIR MANAGEMENTS
Pirtunia Nyaazani Mushaau
INTRODUCTION
IUBACCO MOSAIC VIRUS
Diacos Management
Disease Management
DEAN YELLOW MOSAIC VIRUS
Diagona Managament
Disease Management
Medsules Targeting Sources of Infection
Gultural Directed Towards Vector Avoidance/Incidence Reduction
United Fractices 60
Prints Fector Control 09
Dreeding for vector Resistance
TOMATO SPOTTED WILT VIDUS
Infection Biology 70
Tomato Spotted Wilt Virus Management
Integrated Past Management
Integratea I est Management
Rouging of TSWV-infected Plants 72
TSWV_resistant Plant Varieties
CUCUMBER MOSAIC VIBUS
Infection Biology 73
Disease Management 74
Control of Aphid Vector 74
CMV-resistance Varieties
Cultural Management 75
BEAN COMMON MOSAIC VIRUS
Disease Biology 76
Disease Management 76
Planting Date 76
Cultural Control

CONCLUSION	77
LIST OF ABBREVIATIONS	77
CONSENT FOR PUBLICATION	78
CONFLICT OF INTEREST	78
ACKNOWLEDGEMENT	78
REFERENCES	78
CHAPTER 5 ECONOMIC IMPORTANCE AND CONTROL OF VERTEBRATE PESTS IN LEGUMES	83
Hafiz A Badmus and Abideen A Alarane	05
INTRODUCTION	84
RODENTS AND BIRDS AS VERTEBRATE PESTS OF LEGUMES	84
IMPACT OF VERTEBRATE PESTS ON LEGUMES	85
CONTROL OF VERTEBRATE PESTS OF LEGUMES	86
Rodent Pests	86
Sanitation/Hygiene	00
Freducion	00
Habitat Modification	00
Tran Barrier System	00
Non-lethal Avian Control Methods	0)
Caga Control	89
Loosa Nata au Sumthatia Stuanda	09
Loose mets of Synthetic Strunus	09
Diru scurers	90
Sound Making Davies	90
Chamical Papallant	90
	91
LETHAL CONTROL	91
Killing of Dirds Using Chemical Poisoning	91
	92
CONCLUSION	92
CONSENT FOR PUBLICATION	92
CUNFLICT OF INTEREST	92
	92
KEFEKENCES	93
CHAPTER 6 EFFECT OF SPIDER DIVERSITY AND ABUNDANCE IN LEGUME AGROECOSYSTEMS	95
Mokgadi Asnath Modiba, Sinorita Chauke and Yolette Belinda Rapelang Nyathi INTRODUCTION	95
BIOLOGY OF SPIDERS	96
Structural Morphology and Life Cycle	96
IDENTIFICATION AND DISTRIBUTION	99
ABUNDANCE AND VALUE OF SPIDERS IN AGRICULTURE	. 101
IMPACT OF SPIDERS ON LEGUME CROPS	. 101
OTHER PROBLEMS ASSOCIATED WITH SPIDER INFESTATIONS	105
PREVENTION AND CONTROL OF SPIDER MANIFESTATIONS	. 105
CONCLUSION	107
CONSENT FOR PUBLICATION	107
CONFLICT OF INTEREST	107
ACKNOWLEDGEMENTS	107
REFERENCES	107

Aringo Mukatuni	
DIALACY OF DEAN LEAF DEETLE CODN FADWODM AND STINKDUC	TINSECT
DIOLOGI OF DEAN LEAF DEETLE, CORN EAR WORM AND STINKDUC DESTS	JINSEC
Bean Leaf Beetle (Cerotoma trifurcata Family Chrysomelidae)	•••••
Corn Earworm (Helicoverna zea Family Noctuidae)	• • • • • • • • • • • • • • • • • • • •
Stinkbug (Halvomornha halvs Family Pentatomidae)	
EFFECT OF CLIMATE-RALATED FACTORS ON ECOLOGY AND SPECI	ES
DISTRIBUTION	
Bean Leaf Beetle (Cerotoma trifurcata, Family Chrysomelidae)	
Corn Earworm (Helicoverpa zea, Family Noctuidae)	
Stinkbug (Halvomorpha halvs, Family Pentatomidae)	
HOW DOES CLIMATE-DRIVEN FACTORS AFFECT INSECT PESTS?	
Temperature	
Relative Humidity/Precipitation Patterns	
Rising Atmospheric CO <sub>2</sub>	
IMPACT OF INSECT PESTS ON SOYBEAN GROWTH AND PRODUCTIV	ITY
CHEMICAL CONTROL	
BIOLOGICAL CONTROL	
BIOTECHNOLOGICAL CONTROL	
CONCLUSION	
LIST OF ABBREVIATIONS	
CONSENT FOR PUBLICATION	
CONFLICT OF INTEREST	
ACKNOWLEDGEMENT	
REFERENCES	
PTER 8 SUSTAINABLE CROP NUTRITION FOR AMELIORATING BIOT	IC STRE
RAIN LEGUMES AND ENSURING FOOD SECURITY	IC SIM
Sifau A Adeiumo	••••••
INTRODUCTION	
CROP NUTRITION AND BIOTIC STRESS RESPONSES	
Mechanisms of Nutrients Induced Resistance	
NUTRIENTS REQUIREMENTS BY LEGUMES AND THEIR FUNCTIONS	
Macroelements	
Micronutrients	
CONCLUSION	
CONSENT FOR PUBLICATION	
CONFLICT OF INTEREST	
ACKNOWLEDGEMENT	
REFERENCES	
DTED A DIIVCIAL ACIAL DECRANCE OF LEADINES TO COMPLETE	
APTER 9 PHYSIOLOGICAL RESPONSE OF LEGUMES TO COMBINED	
IKUNNIEN I AL SI KESS FAUTUKS	•••••
IJeaolapo O. Adeoara INTRODUCTION	

Diseases Caused by Bacteria and Nematodes145Insect Pests145Weed Plants145PHYSIOLOGICAL EFFECTS OF BIOTIC STRESS ON LEGUMES146PLANT RESISTANCE TO BIOTIC STRESS146ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	Viral Plant Diseases
Insect Pests145Weed Plants145PHYSIOLOGICAL EFFECTS OF BIOTIC STRESS ON LEGUMES146PLANT RESISTANCE TO BIOTIC STRESS146ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	Diseases Caused by Bacteria and Nematodes
Weed Plants145PHYSIOLOGICAL EFFECTS OF BIOTIC STRESS ON LEGUMES146PLANT RESISTANCE TO BIOTIC STRESS146ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	Insect Pests 145
PHYSIOLOGICAL EFFECTS OF BIOTIC STRESS ON LEGUMES146PLANT RESISTANCE TO BIOTIC STRESS146ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	Weed Plants
PLANT RESISTANCE TO BIOTIC STRESS146ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	PHYSIOLOGICAL EFFECTS OF BIOTIC STRESS ON LEGUMES 146
ABIOTIC STRESS IN LEGUMES147PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	PLANT RESISTANCE TO BIOTIC STRESS
PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES148PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	ABIOTIC STRESS IN LEGUMES 147
PLANT RESISTANCE TO ABIOTIC STRESS150COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	PHYSIOLOGICAL EFFECTS OF ABIOTIC STRESS ON LEGUMES 148
COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS151CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	PLANT RESISTANCE TO ABIOTIC STRESS
CONCLUSION152LIST OF ABBREVIATIONS152CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	COMBINED BIOTIC AND ABIOTIC STRESS EFFECTS 151
LIST OF ABBREVIATIONS	CONCLUSION
CONSENT FOR PUBLICATION153CONFLICT OF INTEREST153ACKNOWLEDGEMENT153	LIST OF ABBREVIATIONS
CONFLICT OF INTEREST	CONSENT FOR PUBLICATION
ACKNOWLEDGEMENT 153	CONFLICT OF INTEREST
	ACKNOWLEDGEMENT
<b>REFERENCES</b>	<b>REFERENCES</b>
SUBJECT INDEX	UBJECT INDEX 161

## FOREWORD

Legumes play important roles in human diets. They serve as the main source of proteins especially for resource-poor families. They represent important sources of human and animal feeds that are rich in protein. More importantly, by their symbiotic interactions with nitrogenfixing bacteria, apart from their contribution to food security and nutrition, they play a major role in climate change mitigation by serving as an alternative and sustainable strategy for improving soil fertility. Though, the Green Revolution in agriculture has helped in meeting the demands for food security by developing new crop varieties and increasing the use of synthetic nitrogen (N) fertilizer that is also contributing to climate change,, legume production does not depend on the use of synthetic fertilizers. It rather improves soil nutrient status and reduces over-dependence on nitrogen fertilizers. Legumes, therefore, should be considered key components in a sustainable agronomic programme. Their production, however, faces many challenges which are grouped under biotic and abiotic stresses.

To take advantage of these potential benefits of legumes, there is a need for a thorough understanding of the challenges faced by farmers in growing leguminous crops. High up on the list of challenges are the threats posed by a range of biotic stresses. It is therefore of immense value that these stresses are so effectively described in this volume. It is a comprehensive and expansive consideration of how biotic stress impacts legumes and how they can be managed. Further, as the authors are all working in Africa, they offer a unique perspective on the potential of legumes in a continent that is witnessing a substantial increase in human population and where climate change is also a major concern. The United Nations estimates that the human population will reach 8 billion at the end of 2022, representing an increase of one billion new mouths to feed. Against this background, the increase in the production of leguminous crops offers obvious attractions. I, therefore, unequivocally recommend this book to agronomists and to general science readers.

Luis Mur

Director of Research: Biology and Health Aberystwyth University, Aberystwyth UK

## PREFACE

When the first volume of Advances in Legume Research was published in 2020 it was not anticipated that this next volume would soon begin, with so much interest of our authors sparked by the previous one. As the previous volume reported a vast amount of advanced information regarding both biotic and abiotic stress-induced reductions in the growth and yield of legumes, particularly, cowpea, mung bean and soybean. Presently, we focussed the current volume on pertinent literature and specific new developments that belong to the topic, as chosen for this book. As earlier envisioned, this book is intended to share new developments pertaining to the ways in which biotic stress factors continue to inflict harm on leguminous crops, as they are among the most vulnerable and highly sensitive groups of oilseed crops worldwide. Although it is aimed at both experienced and newcomer researchers/ students, this book offers new insights for individuals looking for new perspectives in the current knowledge of diseases and pests, associated with legumes, as well as the mechanisms in which these crops may or may not resist these attacks. Mostly, the book focuses on the influences of bacteria, fungi, viruses, arthropodous spiders and invertebrate organisms, as well as how climate change drives the population diversity and distribution of these microbial pests in order to limit plant growth and productivity in leguminous crops.

Such a book is highly required, especially to grow our knowledge and understanding of how the genetic diversity of crop plants can be protected, improved and sustained to benefit the current and future generations. This endeavour can be beefed up by establishing efficiently analysed genomics and proteomics data that provide concrete insights underlining molecular mechanisms that play a critical role in enabling crops to effectively adapt and respond to biotic stress, as highlighted in the introductory chapter of this book. As we look ahead to the possible preparation of the next volume, we hope that readers of this and previous volumes will find time and space to provide us with critical comments, suggestions or errors, if any. Finally, we are very indebted to Dr. Mabila and Ms. Noko Monene (Department of Research Administration and Development, University of Limpopo, South Africa) for their continued financial support, Prof. Luis Mur for providing his expertise outlook and reasons why readers must read this book. Also, many thanks are due to our publisher for all the help we received and for patiently waiting for documents. We are especially grateful to the authors and everyone who assisted over the period of preparing this volume.

#### **Phetole Mangena**

Department of Biodiversity School of Molecular and Life Sciences Faculty of Science and Agriculture University of Limpopo, Limpopo Province Republic of South Africa

Sifau A. Adejumo Department of Crop Protection and Environmental Biology Faculty of Agriculture University of Ibadan, Ibadan Nigeria

# ACKNOWLEDGEMENT

Yet again, the paramount goal of delivering a comprehensive book that clearly elucidates the understanding of physiological and genetic mechanisms to confer biotic stress resistance was made possible by all contributors. As such, we are very much grateful to all the authors and everyone who provided their high-quality contributions. We express our special thanks and appreciation to Bentham Science for the support and help in making this Volume 2 achievable.

#### **Phetole Mangena**

Department of Biodiversity School of Molecular and Life Sciences Faculty of Science and Agriculture University of Limpopo, Limpopo Province Republic of South Africa

Sifau A. Adejumo Department of Crop Protection and Environmental Biology Faculty of Agriculture University of Ibadan, Ibadan Nigeria

# **List of Contributors**

Abideen A. Alarape	Department of Wildlife and Ecotourism Management, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria
Arinao Mukatuni	Department of Chemical Sciences, Faculty of Science, University of Johannesburg, Doornfontein Campus, P. O. Box 17011, Johannesburg 2028, South Africa
Benjamin Joshua	Department of Crop Protection, Georg August University, Gottingen, Germany
Hafiz A. Badmus	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria
Ifedolapo O. Adebara	Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria
Josephine Malatji	Department of Microbiology, Biochemistry and Biotechnology, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Mokgadi Asnath Modiba	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Phetole Mangena	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Phumzile Mkhize	Department of Microbiology, Biochemistry and Biotechnology, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Pirtunia Nyadzani Mushadu	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Sifau A. Adejumo	Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria
Sinorita Chauke	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa
Yolette Belinda Rapelang Nyathi	Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

## **Biotic Stress and Breeding of Plants for Stress Resistance**

Phetole Mangena<sup>1,\*</sup> and Sifau A. Adejumo<sup>2</sup>

<sup>1</sup> Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

<sup>2</sup> Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

Abstract: Among the different environmental challenges that affect crop production, biotic stress factors are more devastating. They reduce crop yield and pose serious threats to food security. Legumes constitute a large number of crop varieties that are seriously affected by different biotic stress factors. To enhance their growth in the face of these different stressful factors and preserve their useful genomic and functional growth properties, leguminous crops are subjected to continuous genetic manipulations for stress resistance. Successful breeding of stress-tolerant varieties for cultivation under different farming systems may result in reduced crop losses and production costs, limited use of agrochemicals, and eventual yield increases. Crops that are resistant to biotic stress also exhibit better growth and yield characteristics. As established several decades ago, the revolution in genomic research led to the development of many sophisticated and advanced crop improvement techniques that can be applied across a whole range of leguminous crop species such as cowpea, faba bean, lentil, mungbean, pea, soybean, etc. However, interest in genetic engineering, chemically-or-physicaly-based mutation breeding, marker-assisted selection, quantitative trait loci and genome editing (CRISPR-Cas) have expanded research beyond biotic stress resistance. These techniques play a key role in applications such as the manufacturing of bioenergy, and crop engineering for the expression of valuable bioactive compounds and recombinant proteins. This chapter briefly reviews the diversity of biotic stress factors (bacteria, fungi, insects, parasitic nematodes and viruses) and possible ways in which these stress factors can be managed and eradicated using various breeding methods. The review shows that the biotechnological tools mentioned above provide beneficial functions in pest management through genetic, physiological and morphological improvements, especially when coupled with other farming practices.

Keywords: Biotic stress, Genetic engineering, Resistance, Leguminous crops.

\* **Corresponding author Phetole Mangena:** Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa; Tel: +2715-268-4715; E-mail: phetole.mangena@ul.ac.za

> Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

#### **DEFINING BIOTIC STRESS**

Biotic stress can be broadly defined as any living component of the environment that prevents the plant from achieving its full genetic potential. Therefore, biotic stress refers to all negative influences caused by living organisms such as parasitic nematodes, viruses, disease-causing bacteria, fungi, arachnids, weeds, and insect pests. According to Gull et al. [1], biotic stresses reduce growth rates and cause major pre- and post-harvesting losses. The stress negatively influences the rate of photosynthesis as a result of reduction in leaf area, for instance, by insect pests. Microbial pathogens such as Xanthomonas axonopodis pv. citri also reduce photosynthesis by negatively affecting the activity of key enzymatic proteins such as Rubisco (ribulose 1,5 bisphosphate carboxylase), Rubisco activase and ATPase (Adenosine Triphosphate synthase) [11]. Taiz et al. [2] therefore referred to this kind of stress, including abiotic stress, as growth-inhibiting conditions that may not allow plants to achieve maximum growth and reproductive capacities. Legumes are one of the major groups of crop species serving as the most important components of both smallholder and large-scale farming systems across the tropical and subtropical regions and are severely affected by this kind of stress. These crops are predominantly cultivated in regions such as Asia, sub-Saharan Africa and Latin America where they serve as critical sources of goodquality dietary proteins, minerals, and oils.

The high value of legume grain seeds in promoting human and animal livelihoods, economic benefits and the improvement of soil quality (through the establishment of symbiotic relationship with nitrogen-fixing bacteria) led to several crop species being opted for cultivation as either monocrops or mixed cropping systems with cereals. However, they are more susceptible to different biotic stresses compared to other non-leguminous crops because of their proteinous nature. Their vegetative and yield characteristics, such as plant height, leaf/branch number, biomass, fruit and seed quantities are all affected by biotic stress. Some common microbial and insect pests that cause damage and diseases in legumes and other crops are summarised in Table 1. The table indicates some of the most common types of living organisms that co-exist with plants in their immediate environment. Although some of these organisms have mutually beneficial interactions with plants, others could be parasitic or pathogenic species and become detrimental to plant growth. These organisms include microbial pathogens like Xanthomonas campestris pv. phaseoli, Fusarium oxysporum f.sp. ciceris, Leveillula taurica cv. Arn, Alfalfa mosaic virus (AMV) and herbivorous insects like leafhoppers as well as beetles (Table 1), including the arthropods not indicated in the table

#### **Biotic Stress and Breeding**

#### Advances in Legume Research, Vol. 2 3

Category	Species	Disease/ Common Name	References
Bacteria	Pseudomonas syringae pv. phaseolicola	Halo blight	Schwartz [3]
-	Pseudomonas syringae pv. syringae	Bacterial brown spot	
-	Xanthomonas campestris pv. phaseoli	Bacterial blight	]
Fungi	Fusarium oxysporum f.sp.ciceris	Fusarium wilt	Hardaningsih [4]
-	Fusarium solani	Black root rot	
-	Leveillula taurica cv. Arn	Powdery mildew	
-	Erysiphe spp.	Powdery mildew	
-	Uromyces cicer-arietini [Gorgn.]	Rust	
-	Rhizoctonia spp.	Dry/wet root rots	
-	Sclerotium rolfsii	Collar rot	
Nematodes	Meloidogyne spp.	Root knot	Davis and Mitchum [5]
Viruses	Alfalfa Mosaic Virus (AMV)	-	Chatzivassiliou [6]
-	Beet Western Yellow Virus (BWYV)	-	
-	Broad Bean Mosaic Virus (BBMV)	-	
-	Seed Borne Mosaic Virus (SBMV)	-	
-	Broad Bean Wilt Virus (BBWV)	-	
-	Bean Golden Mosaic Virus (BGMV)	-	
Insects pests	Empoasca spp.	Leafhopper	Edwards and Singh
-	Aphis craccivora	Aphid	[7] Singh and yan
-	Ophiomyia phaseoli syn. Melanagromyza phaseoli	Beanfly	Emden [8]
-	Ootheca mutabilis,	Beetle	]
-	Mylabris spp.	Bettle	
-	Medythia guaterna,	Beetle	
-	Nezara spp	Bug	]
-	Anoplocnemis spp	Bug	]
-	Riptortus spp.	Bug	
-	Acanthomia spp.	Bug	]

Table 1. Some of the most common biotic stress factors negatively affecting leguminous crops under diverse environmental conditions.

In response to biotic stress, plants have evolved intricate defense mechanisms to deal with the harmful effects of pests and microbial pathogens. These involve

# **Current Knowledge on Biotic Stresses affecting Legumes: Perspectives in Cowpea and Soybean**

Benjamin Joshua<sup>1,\*</sup>

<sup>1</sup> Department of Crop Protection, Georg August University, Gottingen, Germany

Abstract: Legumes are economically important crops for the achievement of food security status in many countries in the tropical and subtropical regions of the world. Among various environmental stresses, biotic constraints to the production of grain legumes such as cowpea and soybean are becoming increasingly significant with the recurring change in climatic patterns and diverse environmental alterations. The economic impact of biotic factors such as disease-causing pathogens (fungi, bacteria, viruses and nematodes), insect pests and parasitic weeds has become overwhelming. These biotic stressors induce a wide range of damage symptoms which include stunting, wilting of stems, defoliation, root rots and premature death of plants. Yield losses due to the activities of biotic stress factors have been very significant. Hence, it is imperative to be informed of the various biotic stressors that affect the growth and yield potential of cowpeas and soybeans in various cropping systems. This review seeks to highlight existing pests and diseases in cowpea and soybean and evaluate their impact on the growth and productivity of these crops. It is hoped that the review will further spur scientific research into how these biotic factors can be managed or even manipulated to ensure agricultural sustainability, high economic returns, and global food security.

**Keywords:** Biotic Stressors, Cowpea, Diseases, Environmental Stress, Legumes, Food Security, Pests, Soybean.

#### **INTRODUCTION**

Leguminous crops belonging to the family Fabaceae are considered the most important grain crops after the grass or Gramineae family (*Poaceae*) [1]. Seeds of legumes are broadly used as direct food sources due to their high nutritional content and the presence of bioactive compounds such as flavonoids and polyphenols as well as micronutrients like essential vitamins and minerals [2, 3]. Amongst the leguminous crops, grain legumes such as peanuts, soybeans, dry

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

<sup>\*</sup> Corresponding author Benjamin Joshua: Department of Crop Protection, Georg August University, Gottingen, Germany; Tel: +4915752071661; E-mail: benjaminjoshua1997@gmail.com

Current Knowledge on Biotic Stresses

beans, cowpeas and chickpeas, are considered key components of the human diet as they serve as the major supply of proteins [3]. The economic importance of grain legumes cannot be underemphasized as their mean annual global production from 2008 to 2017 is estimated at over 75 million tonnes [4]. About 14.5% of the global arable cropped area was occupied by grain legumes in 2014 [5].

Grain legumes are also critical sources of plant nutrients in a cereal production system as they possess the ability to incorporate biological nitrogen into the soil [6]. Hence they are crucial to the food security status of many regions of the world especially Africa. Like many other important food crops, legumes are vulnerable to different environmental stresses which could be abiotic or biotic [7, 8]. Abiotic stresses affecting legumes include drought, salinity, heat, high light intensity and nutrient imbalance [9], while major drivers of biotic stress include viruses, fungi, bacteria, nematodes, weeds and other parasites [10]. The occurrence of any stress conditions certainly affects the yield potential of legumes [8]. The composition and quality of grain legumes are negatively impacted by abiotic and biotic stresses [11].

These stress factors can influence the yields of legumes and other beneficiary cereals within a crop production system by inhibiting or promoting nodulation [12]. The response of legumes, like other crops, to environmental stresses varies based on the type of stress (biotic or abiotic), stress severity and plant vigour [13]. Although research shows that abiotic stress factors are known to impact legume production extensively [8, 11, 14, 15], biotic stresses are becoming more frequent owing to global warming and climate abnormalities [16, 17]. Hence, current knowledge of various biotic stress conditions affecting legumes, especially grains, will be more insightful.

#### **BIOTIC STRESSES IN LEGUMES**

Generally, legume growth and development are inhibited by many kinds of biotic stresses that induce direct and indirect physiological alterations [13]. These stress agents directly induce a deprivation of nutrients required by the host crop and can lead to the death of plants. High severity of biotic stress can bring about heavy pre- and postharvest losses [15]. Predominantly, the extent of damage influenced by biotic factors on legumes is highly dependent on the prevalence of one or more abiotic factors [9]. However, the major biotic stressors that can drastically reduce the yield of grain legumes predominantly involve microbial pathogens, pests, and weeds [18]. Therefore, the economic significance of the different biotic factors affecting the two major food legumes; cowpea and soybean, is then discussed below.

#### **COWPEA**

Cowpea (*Vigna unguiculata* L. Walp.) is arguably the most widely adapted, versatile and nutritious grain legume for both warm and dry agro-ecologies of the tropics and subtropics [19]. Cowpea belongs to the family Fabaceae and it is often called black-eye pea, southern pea or crowder pea. It is predominantly unique as a self-fertilizing crop [20]. Through all stages of development, it grows in a wide range of temperature from 18 to 28 °C. In Sub-Saharan Africa, it is widely grown for food and feed because its grain contains high proportion of protein (23 to 32%), energy, micro- and macro-nutrients [21, 22]. Being tolerant to harsh conditions, it is considered a valuable component in crop production systems of poor rural households [23]. Owing to its atmospheric nitrogen fixation ability, it readily serves as a crop for rotation with major cereals crops which are the main determinants of food security in developing countries [24]. Global production of cowpea in 2019 was over 8.9 million metric tonnes of which Africa accounted for over 97% [25, 26] (Fig. 1) (Table 1).



Fig. (1). Production of cowpea based on different regions of the world. FAOSTAT [26].

# **Indexing for Bacterial, Fungal and Viral Pathogens in Legume Plants**

Phumzile Mkhize<sup>1,\*</sup>, Josephine Malatji<sup>1</sup> and Phetole Mangena<sup>2</sup>

<sup>1</sup> Department of Microbiology, Biochemistry and Biotechnology, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

<sup>2</sup> Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

**Abstract:** Microorganisms found in plants exist as epiphytes or endophytes. Most epiphytes remain on plant surfaces and the latter may be intracellular pathogens, opportunistic and adapted microbial colonisers that originate from the surrounding environment. The main purpose of agricultural practices is thus, to develop disease-free varieties by propagating plants under controlled environmental conditions. Such conditions should be optimal for plant production and reduce disease development. The former requires strict certification schemes *via* several routes that include (i) indexing with subsequent removal of infected or contaminated materials from the production chain (ii) meristem and other tissue culture production systems and (iii) the use of thermo or chemotherapy for phytosanitation. Other methods also require balancing and proper adjustments in fertilizer usage and crop rotation. Therefore, this chapter reviews the role of microbial pathogen indexing as a means of controlling bacterial, fungal, and viral diseases that have a significant role to play in agriculture.

**Keywords:** Agriculture, Bacterial diseases, Fungal diseases, Indexing, Microorganisms, Microbial pathogens, Viral diseases.

#### **INTRODUCTION**

Microorganisms found in plants exist as epiphytes or endophytes. Most epiphytes remain on the plants' surface and the latter may be intracellular pathogens, opportunistic and adapted microbial colonisers that originate from the surrounding environment [1]. The adverse effect of the presence of bacterial infections in most legumes cannot go unnoticed as they affect growth, and cause leaf spots, specks and blights, galls, and cankers [2]. Among the bacterial diseases in plants, those that are caused by gram-negative bacteria are the most widespread and destructive. The bacteria of the genus *Pseudomonas*, *Ralstonia*, *Agrobacterium*, *Xanthomonas*, *Erwinia*, *Xylella*, *Pectobacterium*, and *Dickeya* [3] are among the

<sup>\*</sup> **Corresponding author Phumzile Mkhize:** Department of Microbiology, Biochemistry and Biotechnology, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa; Tel: +2715-268-3017; E-mail: Phumzile.Mkhize@ul.ac.za

#### 38 Advances in Legume Research, Vol. 2

most disruptive genus causing great losses to the agricultural industry. They have a broad crop host range that includes leguminous and non-leguminous crops such as cotton, rice, cereals walnut, soybean, and sugarcane.

These pathogens affect different plant parts including the leaves, stems, and fruits. Unlike viruses, most bacterial plant diseases do not require insects as a vector, but rather rain, wind, soil, seed dispersal or any other means of transport to gain entry into the plants. Microbial pathogens are generally eliminated by chemical microbicides that usually contain copper in combination with ethylene bis-dithiocarbamate like mancozeb, streptomycin and oxytetracycline [4]. Approximately 300,000 species of flowering plants that include cereals, lumber, pulses, barley, corn, rice, sorghum, wheat, and nuts house over 100,000 fungal species. Those include fungal species such as *Magnaporthe oryzae*, *Botrytis cinerea*, *Puccinia* spp., *Fusarium graminearum*, *Fusarium oxysporum*, *Blumeria graminis*, *Mycosphaerella graminicola*, *Colletotrichum* spp., *Ustilago maydis* and *Melampsora lini* [5–8].

These may be pathogenic and saprophytic fungi that cause the development of several diseases including anthracnose, botrytis rots, downy mildew, *Fusarium* rots, powdery mildews, rusts, *Rhizoctonia* rots, *Sclerotinia* rots and *Sclerotium* rots [9]. These microbes cause deterioration in the growth, yield, and quality of crops, and often result in the utter destruction of superior varieties that are much more valuable for agriculture [10]. For example, dramatic losses of revenue estimated at over 11 million US dollars per year as a result of low seedling survival rates caused by *Fusarium circinatum* have been recorded as reported by Storer *et al.* [10]. Generally, all bacterial, viral, and fungal plant pathogens require a wound to gain entry to cause disease development in plants. Plant tissue wounding caused by beetles (*Ips conophthorus, Ernobium,* and *Pissodes nemorensis*) serves as infection sites in mature plants.

In legumes, these microorganisms have evolved mechanisms to actively transverse the plant's outer structural barriers, the cuticle, and the epidermal cell wall structures. For example, fungal pathogens can secrete a cocktail of hydrolytic enzymes, including cutinases, cellulases, pectinases, and proteases to gain entry into tissues [11]. Moreover, these fungal pathogens can easily spread through contaminated planting pots, irrigation water, and supporting mediums [12]. Viral plant infections cause several complex diseases resulting in necrotic cells, tissues or organs and failure for plant organs to develop fully (hypoplasia) causing dwarfing or stunting. Hypoplasia conditions may also cause tissue overgrowths like the formation of crown gall diseases caused by *Agrobacterium* spp. or club root. The most common symptoms of viral infection in plants range from mosaic patterns, chlorotic, yellowing, and leaf rolling to flower deformation [4].

#### Bacterial, Fungal and Viral Pathogens

Diseases like the Red clover nepovirus A (RCNVA) remain the most detrimental and cause dramatic effects on plant vigour and yield. Moreover, members of the genera *Ampelovirus, Clostrerovirus,* and *Vitivirus* were also found to be more controversial serving as causal agents for leaf roll and rugose wood. Although these viruses are not much implicated in legume crop diseases; however, they generally cause severe diseases which remain difficult to quantify and estimate because of the complexity related to their mode of transmission and symptoms. Commonly, farmers do not become aware of the real damage until it is too late with the losses culminating in the magnitude of millions of Rands every year [13]. Mixed infection, viral strain, environment, and cultivar response to infection are some of the complex mechanisms of viral plant infections that necessitate specific and accurate indexing methods for their effective control [14].

Indexing for bacterial, fungal and viral pathogens in plants permits the production and use of planting material free from phytopathogenic infections. Even though that remains the case, indexing does not exclusively serve as a method of control and prevention for disease development. The approach remains a vital necessity in the agricultural industry. The main purpose is to develop disease-free varieties by propagating plants under controlled environmental conditions. Such conditions should be optimal for plant production and reduced disease development. The former requires strict certification schemes *via* several routes that include (i) indexing with subsequent removal of infected or contaminated materials from the production chain (ii) meristem and other tissue culture production systems and (iii) the use of thermo or chemotherapy [15]. Furthermore, Pant and Hambly-Odame [16] reported that the latter also requires balancing and proper adjustments in fertilizer usage and crop rotation. Therefore, this chapter reviews the role of microbial pathogen indexing as a means of controlling bacterial, fungal, and viral diseases that have a significant role to play in agriculture, especially leguminous crop production.

#### **INDEXING APPROACHES**

The most critical element of developed and optimised indexing systems is that they should not overlook minor infectious microorganisms while focusing on the major ones. Such an approach may be detrimental to the agricultural industry. For example, the impact of minor viruses such as fleck, vein mosaic, and rupestris pitting is amplified by a synergistic negative effect of other major viruses. Furthermore, the mutagenic and revolving nature of microbials may also create a constant spree of emerging new pathogens. The mutagenic rate in viruses is so high such that a single RNA molecule gives rise to a population of mutant sequences (haplotypes or variants) originating from the master sequence

## **Viral Diseases of Legumes and Their Managements**

#### Pirtunia Nyadzani Mushadu<sup>1,\*</sup>

<sup>1</sup> Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

Abstract: Legumes are very important food crops that are widely cultivated for their high-quality proteins, oils, and vitamins throughout the world. In total, 168 viruses are officially assigned by the International Committee on Taxonomy of Viruses. These viruses belong to 39 genera in 16 families and have been reported to affect various leguminous crops in different parts of the world. Among these viruses, TSWV (Tomato Spotted Wilt Virus), CMV (Cucumber Mosaic Virus), TMV (Tobacco Mosaic Virus), BYMV (Bean yellow mosaic virus), and BCMV (Bean Common Mosaic Virus) have global economic importance. This review therefore focuses on the economic importance of the abovementioned viruses influencing legume growth and development by looking at aspects such as viral traits, transmission, viral biology, plant host symptoms and the options used to control and manage some viruses such as the CMV (Cucumber Mosaic Virus), TMV (Tobacco Mosaic Virus), BYMV (Bean yellow mosaic virus), and BCMV (Bean Common Mosaic Virus), and the options used to control and manage some viruses such as the CMV (Cucumber Mosaic Virus), TMV (Tobacco Mosaic Virus), BYMV (Bean yellow mosaic virus), and BCMV (Bean Common Mosaic Virus), BYMV (Bean yellow mosaic virus), and BCMV (Bean Common Mosaic Virus).

**Keywords:** Crop yield, Disease management, Legumes, Plant virus, Viral morphology, Infection biology.

#### INTRODUCTION

Legumes belong to the family Leguminosae (Fabaceae), which is regarded as one of the largest and most important families of flowering plants, constituting about 650 to 750 genera, 18,000 to 19,000 species of herbs, climbers, shrubs, and trees [1]. The family is regarded as podded fruits, and the commonly used legumes include peas, lentils, peanuts, cowpeas, chickpeas, clovers, kidneys, mung beans, pigeon peas, soybean, and vetches. Legumes are used as human and animal food since they are the richest source of protein, starch, minerals, and vitamins. They also play an important role in agriculture and agroforestry by improving soil quality. These legumes can convert atmospheric nitrogen into nitrogenous compounds that are usable by plants [2]. The main limiting factor in legume

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

<sup>\*</sup> **Corresponding author Pirtunia Nyadzani Mushadu:** Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa; Tel: +2771-019-8740; E-mail: nyadzanimushadu@gmail.com

production is yield losses that are due to pests and disease. Among all various pathogens, viruses are considered to pose the most significant effect [3]. The cultivated legumes are susceptible to natural infections caused by viruses, where resultant diseases cause a severe impact on the vegetative growth and productivity of legumes worldwide.

In total, 168 viruses belonging to 39 genera and 16 families were recorded in different parts of the world by the International Committee on Taxonomy of Viruses and they were attributed to major losses in various leguminous crops [4]. TSWV (Tomato Spotted Wilt Virus), CMV (Cucumber Mosaic Virus), TMV (Tobacco Mosaic Virus), BYMV (Bean yellow mosaic virus), and BCMV (Bean Common Mosaic Virus) are the most economically important viruses responsible for legume losses worldwide [5]. Among these, three viruses (TSWV, CMV, and TMV) are among the top economically important plant viruses mostly in non-leguminous crops [6], meanwhile, two viruses (BCMV and BYMV) are particularly regarded as economically important in reducing legume growth and productivity. Most of the legume-infecting viruses are seed-borne, with viral transmission vectored through insect pests [5]. Therefore, this chapter discusses the biology and management of some of the economically important plant viruses reported to date and evaluates their influence on the growth and productivity of leguminous crops.

#### **TOBACCO MOSAIC VIRUS**

The tobacco mosaic virus was discovered for the first time in 1879 by Adolf Mayer in the Netherlands [7]. In plant virology, the TMV is the most ancient virus and a member of the *Tobamovirus* group, which includes the *Odontoglossum* ringspot virus as well as the Sammon's opuntia virus. Numerous strains of Tobacco Mosaic Virus exist, where each strain causes different symptoms in both fruit and foliage crops [8, 9]. However, TMV can remain infective for many years, while attached to the materials used for plant support such as soil particles, culture medium, greenhouse surface, and greenhouse structures [9]. This is due to its ability to withstand high temperatures of up to 50°C [8, 10, 11]. TMV is the positive sense single-stranded (ssRNA) virus [8], however, it was also recognized first because of its easiness to affect plants and noticeable symptoms [12].

Tobacco mosaic virus was reported to be a widely distributed virus that affects several vegetables, ornamental and leguminous plants, as well as various species in Solanaceae [12, 13]. The TMV is not transmitted by insects, nematodes, or other vectors, however, it has been reported to be transmitted easily by virus-infested saps [10], particularly, through direct contact with wounded areas on the surfaces of plants [11, 14]. This virus can also be transferred by grafting seed

#### 66 Advances in Legume Research, Vol. 2

coats to new plants from the infected mother plants [12]. The virus can also be disseminated mechanically during normal field operations and human activities [9, 10].

#### **Infection Biology**

Different pathogens that infect plants interfere with various physiological functions which often results in the development of different symptoms. Changes that result from the multiplication of the virus cause a reduction in plant yield and reduced quality of the product [15]. Symptoms in infected plants vary according to the strains of the Tobacco Mosaic Virus, the type of plant species that get infected, and the developmental stage at which a particular plant is infected [12]. Pepper plants infected by the virus developed recognisable disease symptoms early in their seedling and immature stages [15]. However, all viral diseases are generally associated with direct or indirect biochemical aberration induced by the virus. It has also been reported that the first symptoms after virus infection appear as necrosis and chlorosis on the uppermost younger leaves along the main veins, followed by wilting and leaf spots [15].

Generally, the infected pepper shows reductions in leaf numbers, leaf area, mottled leaves, deformed and distorted leaf phenotype, as well as stunted shoot growth. As such, this contributes to a reduction in photosynthetic activity. Photosynthetic activities provide the plant with the energy that is required for its growth and defence against diseases and pests. Since MTV is associated with the reduction in leaf numbers and total leaf area, which are parameters linked to photosynthesis, this reduction causes a decline in plant growth, resulting in shortened slender plant stems, and reduced biomass. Infections caused by TMV also cause a reduction in relative water content and photosynthetic pigments (chlorophylls) [15]. Compared to leguminous crops, infected tobacco plants produce TMV more abundantly than enclosed crystallized virion bodies [11]. The first symptoms in tobacco plants are vein clearing at the youngest leaves, followed by a distinct mosaic of light-green and dark-green areas at early developmental stages [10]. Mosaic symptom development involves changes in chloroplast structures whereby some of the TMVs are detected earlier in chloroplast metabolism [16]. The virus causes light and dark green mottled areas in tomato leaves. In most cases, the area appearing dark green becomes thicker than the portion of the leaf which is lighter in colour. Young shoot growth usually becomes stunted with distorted leaf curling. Additionally, some strains produce mottling, streaking and death of the fruits [12]. Tobacco Mosaic Virus infection resembles water stress which also causes an increase in cytoplasmic ABA. Generally, the TMV infection causes a two to six-fold increase in the concentration of ABA in the leaf. The ABA is important in controlling the

# **Economic Importance and Control of Vertebrate Pests in Legumes**

Hafiz A. Badmus<sup>1,2,\*</sup> and Abideen A. Alarape<sup>3</sup>

<sup>1</sup> Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

<sup>2</sup> Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

<sup>3</sup> Department of Wildlife and Ecotourism Management, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria

Abstract: One of the constraints to crop production across the world is vertebrate pests. They have been implicated as the most destructive pests which inflict both preharvest and post-harvest damages on agricultural production. Legumes are one of the crops usually attacked by vertebrate pest species, though the degree of depredation varies from one crop type to another. Meanwhile, there has been a misconception among farmers, especially in some of the developing countries, that vertebrate pest species belonging to the order Rodentia are very difficult to control. This is evident in their crop cultivations whereby two rows are planted in addition to every eight rows of crop, for rodent pest species that may come and inflict damage on the cultivated crop. Some of the rodent pest species that cause economic damage to legumes on the field include Arvicanthis niloticus, Xerus erythropus, Cricetomys gambianus, Rattus rattus, R. norvegicus, and Mus sp., while avian pest species include Francolinus bicalcaratus, and *Ploceus cucullatus*. There is a need to effectively manage these vertebrate pest species. Some of the rodent pest management approaches include the use of sanitation measures, exclusion of the vertebrate pest species, and modification of their habitat, and Trap Barrier System, while some of the avian pest management approaches include cage, nets or synthetic fibres, bird scarers, chemical repellents, sound-making devices, chemical poisoning, and trapping.

**Keywords:** Legumes, Rodent pests, Pre-harvest damage, Post-harvest damage, Avian pests, Management approach.

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

<sup>\*</sup> **Corresponding author Hafiz A. Badmus:** Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa; & Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria; Tel: +234-803-826-7691; E-mail: badmus.hafiz@gmail.com

#### **INTRODUCTION**

Vertebrate pests are pest animals characterized by the possession of a backbone. They are any vertebrate whether indigenous or exotic, wild or domestic, that has been implicated as the causes of economic, environmental, social, and health problems [1]. Species of vertebrates known to be pests could be found in any of the vertebrate classes which include amphibians, reptiles, birds, and mammals. However, class Mammalia has the highest pest species followed by class Aves [2]. Among the class Mammalia, rodent pest species have been identified as the most destructive categories of pests, globally [3]. Unfortunately, they are the most often overlooked pest species especially in developing countries and so are given little or no attention [4]. Even though a lot of people in developing countries share their insufficient households and diets with rodents and avian pest species, scientists and agriculturists are still not able to properly document quantitative losses by these vertebrate pest species. A twofold loss which comprised a percentage of their produce both at pre- and postharvest stages is suffered by the farmers' households [5]. Enormous amounts of produce damage and scarcities in some continents have been reported to be caused by vertebrate pest damage, particularly, by rodents [6]. Small mammals inflict a greater danger to crops of peasant farmers in Africa due to the injury and losses caused by them and their high costs of management compared to other countries worldwide [7].

Small mammals pose a significant constraint to crop production in agricultural ecosystems globally and managing them is still a major problem for researchers and agriculturalists. While few studies are relatively available to provide correct estimations of losses of crops due to rats in African countries, new research on farmer's familiarity, attitude, and practices in rat management showed that small mammals are regarded as the most persistent pest to manage [8, 9]. About 25 small mammal species have been recorded as pests in agriculture in African countries, causing different damage and losses in different crops [7]. According to the estimate, about one-fifth of the produce cultivated yearly worldwide are never consumed by individuals because of rodents-inflicted injury [10]. Aves can wreak injury to the vegetative and reproductive stages of all agricultural crops, starting from sowing, planting, and harvesting. Old-style methods usually rely on scaring birds by just rebounding the avian species to adjoining growing crops. However, it is an expensive management strategy [11].

#### **RODENTS AND BIRDS AS VERTEBRATE PESTS OF LEGUMES**

For small mammals (rodents and insectivores), damage to legumes is negligible [5]. Except for groundnuts, grain legumes are not the favorite foods of rats and mice. Most losses are not due to rodents but fungi and invertebrates of the class

Vertebrate Pests in Legumes

Insecta. Skilled viewers come to an agreement that losses of legumes after harvest frequently surpass those of cereal crops. In addition, the avian damage to grain legumes is restricted to the field where avian pest species such as *Ploceus cucullatus* (weaverbirds) depredate the crop by removing the seeds from the pod [12]. Birds that do not live inside the farm or village structures like rodents, hardly ever depredate stored produce. Only the out-of-door conditions where cereals or legumes are unprotected during processing that aves can consume them, or they may have access to grain produce where they are kept under exposed storage conditions. Thus, the damage to stored produce because of avian activities is minimal compared to those caused by small mammals especially rodent species [1, 5].

#### IMPACT OF VERTEBRATE PESTS ON LEGUMES

Vertebrate pest species, especially those found in the classes Mammalia and Aves, inflict both pre-harvest and post-harvest damages to grain legumes [13]. Table 1 shows some of the legumes and the types of damage done by some vertebrate pests.

Сгор	Type of Damage	Vertebrate Pest Indicted
Arachis hypogaea (groundnut)	Removal of newly sown and germinating seeds	Cane rat ( <i>Thryonomys swinderianus</i> ) Bush fowl ( <i>Francolinus bicalcaratus</i> ) Nile harsh-furred rat ( <i>Arvicanthis</i> <i>niloticus</i> )
	Removal of pods	Red-legged ground squirrel (Xerus erythropus)
	Eating of roots and/or groundnut.	Mole rat (Nesokia indica)
	Removal of groundnut in the pod.	Lesser bandicoot rat ( <i>Bandicota bengalensis</i> )
	Removal of groundnut but the plant is not usually damaged.	Indian gerbil (Tatera indica)
Vigna unguiculata	Nibble on the cowpea grain in the store.	Mouse (Mus minutoides)
(Cowpea)	Gnawing the stored cowpea.	Roof Rat ( <i>Rattus rattus</i> ) Norway Rat ( <i>Rattus norvegicus</i> )
	Eating the seeds inside the pod.	Weaverbird (Ploceus cucullatus)
Pisum sativum (Garden pea)	Destruction of leaves, shoots, and mostly pods and seeds.	Rat ( <i>Rattus sp</i> )

#### Table 1. Vertebrate pests and type of damage inflicted in some leguminous crops.

# Effect of Spider Diversity and Abundance in Legume Agroecosystems

# Mokgadi Asnath Modiba<sup>1,\*</sup>, Sinorita Chauke<sup>1</sup> and Yolette Belinda Rapelang Nyathi<sup>1</sup>

<sup>1</sup> Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa

Abstract: An agroecosystem refers to a complex system comprising a couple of different interacting factors, involving species, ecological, and management processes. This system contains lesser species diversity of both plants and animals than a natural ecosystem. The variation in species of plants and insects is critically important to serve as a complex food chain and web whose interactions function to stabilise this ecological unit. However, among the groups of herbivores and predators found in agroecosystems, spiders play a key role in most crop fields by preying on a variety of pests. Besides this, the current pace of research on this subject shows that the role of spiders in regulating pest species and serving as potential biological control agents has been largely ignored. So far, information on agricultural spider communities, diversity and their role as biological pesticides remain scant in various parts of the world with the exception of countries such as the United States of America, Australia, and some parts of the Middle East Asia. Thus, this chapter outlines the most relevant information on the diversity, abundance and effect of arthropodous spiders on agroecosystems, particularly those that are involved in the cultivation of legume crop species. The paper also discusses current relevant threats to spiders, conservation measures, the threat of species extinction, and the role that these arthropods play in agriculture, especially by reducing the growth and productivity of species such as soybean (Glycine max L.) and cowpea (Vigna unguiculata).

Keywords: Agroecosystems, Arthropods, Legumes, Soybeans, Spiders.

#### **INTRODUCTION**

An agroecosystem refers to a complex system comprising a couple of different interacting factors, involving species, ecological, and management processes [1]. This system contains lesser species diversity of both plants and animals than a natural ecosystem. Typically, one to four major crop species and six to ten major

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers **CHAPTER 6** 

<sup>\*</sup> Corresponding author Mokgadi Asnath Modiba: Department of Biodiversity, School of Molecular and Life Sciences, Faculty of Science and Agriculture, University of Limpopo, Limpopo Province, Republic of South Africa; Tel: +2715-268-4045; E-mail: mokgadi.modiba@ul.ac.za

#### 96 Advances in Legume Research, Vol. 2

pest species can be found in this ecosystem [1, 2]. In most cases, the status and conditions of agroecosystems are largely influenced by anthropogenic activities. Some of these activities include ploughing, inter-cultivation, and application of pesticides, leading to the alteration of the diversity of species, especially of pests. However, influences by man can be more detrimental, causing the agroecosystem to be more susceptible to pest damage and catastrophic outbreaks that are concomitantly attributed to the lack of species diversity. The variations in species of plants and insects are critically important to serve as a complex food chain and web whose interactions function to stabilise this ecological unit [2].

The conversion of ecological units to agriculture also leads to the invasion by unplanned diversity of weed plants, herbivores, predators, microbial pathogens, and other organisms that persist in the system. Among the group of herbivores and predators found in agroecosystems, arthropods spiders play a key role in most crop fields by preying on a variety of pests. However, the current pace of research on this subject shows that the role of spiders in regulating pest species and serving as potential biological control agents has been largely ignored. So far, information on agricultural spider communities, diversity and their role as biological pesticides remain scant in various parts of the world except for countries such as the United States of America, Australia, and some parts of Middle East Asia [3]. The functions of spiders as pest predators for herbivores and granivores remain promisingly beneficial for agriculture and offer an alternative pest management strategy for both small- and large-scale farmers.

Isbister [4] emphasised on the myths and reputation of spiders as also being the "predators of man" or being dangerous to people and animals as one of the main reasons why credit is still due to them for use as important natural pests control agents. But among over 30,000 known spider species, only about twenty-three of species are considered poisonous. As a result, this chapter outlines the most relevant information on the diversity, abundance, and effect of arthropodous spiders on agroecosystems, particularly those that involve the cultivation of legume crop species. The paper also discusses current relevant threats to spiders, conservation measures, threat of species extinction and the role that these arthropods play in agriculture, especially by reducing the growth and productivity of species such as soybean (*Glycine max* L.) and cowpea (*Vigna unguiculata*).

#### **BIOLOGY OF SPIDERS**

#### **Structural Morphology and Life Cycle**

Arthropods are invertebrates that form a significant part of the animal kingdom. They are easily identified and distinguished by the distinct morphological traits that they possess. Their features include an exoskeleton, paired jointed

#### Spider Diversity and Abundance

appendages and a segmented body. They possess abilities to survive in aerial, aquatic and terrestrial environments. For instance, the class Arachnida consists of eleven (11) orders of joint-legged invertebrates that also include spiders [5]. However, compared to other invertebrate animals, spiders form part of the phylum Arthropoda, subphylum Chelicerata [6]. These species are further classified into the order Araneae which consists of 112 families, 4072 genera with approximately 47000 species. The suborder Araneae are classified into two suborders known as the Mesothelae which consists of one family with 87 species which are characterized by traces of segmentation on their abdomen and the Opisthothelae which have no traces of segmentation on their abdomen [7, 8]. The biology of spiders indicates that they all undergo the same general stages of development. In general, many species go through the egg, spiderling, and adult stages as indicated in Fig. (1). But, having stated that slight differences in their developmental stages may obviously exist based on species variation within the taxa. During the egg or embryonic stage, the female spider builds an egg sac using silk and deposits her eggs inside it and fertilize them as they emerge. One egg sac may host up to a hundred eggs depending on the species. The eggs usually take a week to hatch but some spiders, especially those that are found in temperate regions, may employ specific strategies and other unique characteristics such as overwintering of the egg sacs, and then emerge in spring. Some spider species protect their egg sacs while others abandon the egg sacs in secure places. The spiderling stage commences as soon as they hatch from their eggs [9]. At this stage, the spiders are much smaller in size and immediately disperse through a process known as ballooning or walking. Most species become mature after shedding at least ten times. Males are usually fully mature by the time they leave the sac, but female spiders take more time to mature since they are usually larger than male spiders. In the adult stage, spiders become fully developed for mating, and after the events of mating between the two, female spiders will then live and survive for a longer period than male spiders which usually die after this process. The life span of spiders can be up to two years, but variability also exists between different species [3, 9].

Spiders consist of chelicera, which is a pair of appendages in the front of their mouth that allows for tearing apart of their prey instead of chewing. Furthermore, these chelicerae also contain two fangs at their tip which are connected to spiders' poisoning glands [10, 11]. The body of spiders is also divided into prosoma and opisthosoma as previously indicated. The prosoma consists of the eyes and locomotory appendages while the opisthosoma consists of the abdomen. Spinnerets and silk glands secrete silk which is a significant distinguishing character of spiders as earlier described by Haupt [10]. According to Haupt [10], Araneae also contains within its species some of the most venomous web-spiders whereby the venomous capabilities of some of species remain unknown. Spiders

# Role of Climate-Driven Factors on Bean Leaf Beetle, Corn Earworm and Stinkbug Populations, Control and their Effects on Soybean Growth and Productivity

#### Arinao Mukatuni<sup>1,\*</sup>

<sup>1</sup> Department of Chemical Sciences, Faculty of Science, University of Johannesburg, Doornfontein Campus, P. O. Box 17011, Johannesburg 2028, South Africa

Abstract: Soybean is a crucial crop that is recognised globally for its high-value protein, vitamins, carbohydrates, fibre, and oils. However, the production of soybeans is frequently influenced by biotic stress factors such as bean leaf beetles (Cerotoma trifurcate), grasshoppers (Schistocerca americana), corn earworms (Helicoverpa zea) and stinkbugs (Halyomorpha halys). However, these insect pests were discovered to be both beneficial and harmful to crop growth and productivity, particularly, in soybeans. According to the literature, the rise in temperature causes an increase in insect pest populations, thereby severely influencing the growth, and yield quality of many crops. Less precipitation also contributes to drought stress, and plants undergoing waterdeficit stress produce fewer secondary metabolites rendering them vulnerable to attacks by these insects. Similar effects were also revealed due to the rise in atmospheric CO<sub>2</sub> levels that led to the adverse weather effects that caused enhanced reproduction and spread of pest insects. This chapter, therefore, explores the role of climate changeinduced factors, such as temperature, precipitation patterns and rising atmospheric CO<sub>2</sub> on insects' distribution, and reproductive patterns, as well as their subsequent influence on crop growth and productivity in soybeans. The review also briefly discusses the chemical, biological and biotechnological approaches of insect pest control that have been employed effectively to combat losses of crop production. Side effects, cost effectiveness and the ability of new biotechnological methods to target specific pests are also discussed in this chapter.

**Keywords:** Biotic stress, Climate change, Chemical control, Biological control, Insect pests, Genetic engineering, Soybean.

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

<sup>\*</sup> **Corresponding author Arinao Mukatuni:** Department of Chemical Sciences, Faculty of Science, University of Johannesburg, Doornfontein Campus, P. O. Box 17011, Johannesburg 2028, South Africa; Tel: +2772-030-8129; E-mail: arinaom2@gmail.com

Arinao Mukatuni

#### **INTRODUCTION**

Soybean, *Glycine max* (L.) Merr., is a grain legume known to be an important agricultural crop globally and economically. This crop is grown worldwide, however, production is affected by various factors like abiotic, and biotic stress such as drought, feverish temperatures and insect pests. There are over 700 species of plant feeding insects for soybean but, the most notable damage is demonstrated by only eight species of insects found in the United States (US) [1]. These entails the velvetbean caterpillar, *Anticarsia gemmatalis*; the soybean looper, *Pseudoplusia includens*; the green cloverworm, *Plathypena scabra*; the Mexican bean beetle, *Epilachna varivestis*; the bean leaf beetle, *Cerotoma trifurcata*; the green stink bug, *Acrosternum hilare*; and the corn earworm, *Helicoverpa zea* [1, 2]. The bean leaf beetle is a native species in the eastern part of the US and a major pest in all soybean-growing areas across the globe [2].

The larvae of this beetle are said to feed on the roots, root hairs, and nodules of soybean, while the adults defoliate the leaves and feed on the external pod tissues [3]. *Helicoverpa zea* is an economically significant insect and said to be dominant also in the United States of America. This pest largely attacks soybean plants, affecting mainly the leaves during vegetative stages. The size of the *Helicoverpa zea* caterpillar, the development stage of the plant, the time of damage it inflicts, and the plant's ability to recover are some of the factors that can affect the yield of soybeans [4]. However, to compensate for the damage done to the reproductive tissues, soybeans can produce more pods or increase their seed's weight [3, 4]. Furthermore, the harmful insects known as the stinkbugs are also part of the growing problem of soybeans, and they feed on the pods while causing severe damage to the developing seeds [5].

Therefore, this chapter explores the role that insect pests play in soybean fields and examine the influence of climate change-induced factors such as temperature, precipitation patterns and rising atmospheric  $CO_2$  on the insects' distribution, reproductive patterns, as well as their subsequent influence on crop growth and productivity in soybean. The review also briefly discusses the chemical, biological and biotechnological approaches of insect pest control that have been employed effectively to combat losses of crop production. Side effects, cost effectiveness and the ability of new biotechnological methods to target specific pests are also discussed in this chapter.

# **BIOLOGY OF BEAN LEAF BEETLE, CORN EARWORM AND STINKBUG INSECT PESTS**

#### Bean Leaf Beetle (Cerotoma trifurcata, Family Chrysomelidae)

*Cerotoma trifurcate* also known as the bean leaf beetle (BLB) belongs to the Chrysomelidae family, order Coleoptera [6]. Bean leaf beetle are classified according to their appearance in colour. The colour of adult beetles differs from red to orange, as well as light yellow as exemplified in Fig. (1). The wing covers (elytra) of the adult BLB are soft and beige when first spotted. There are four squarish black markings on the underside of the wings, but these can be from few to nothing at all, and they are usually rimmed with a black margin. Black frons (faces) are typically found on female beetles, while tan frons are typically found on male ones [7]. The first tarsal segment of a male beetle also has a covering of dense setae (hairs), which are believed to be part of the mating process, this feature is not there in female beetles [7, 8]. The overall life span of this insect is usually 1 to 2 months [9].



**Fig. (1).** Examples of adult bean leaf beetles with different colours (A-C) [7], corn earworm *Helicoverpa zea* (D) [12] insect pests and adult brown marmorated stinkbug (E) [15].

### **CHAPTER 8**

# Sustainable Crop Nutrition for Ameliorating Biotic Stress in Grain Legumes and Ensuring Food Security

#### Sifau A. Adejumo<sup>1,\*</sup>

<sup>1</sup> Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

Abstract: Environmental stress generally causes considerable yield loss in leguminous crop production. This stress could be biotic (Insect pests, disease pathogens, weeds, vertebrate pests, etc.) or abiotic (Drought, heat, cold, salinity, flooding, heavy metal contamination, etc.). Either biotic or abiotic stress, both are capable of causing total yield loss. Unfortunately, crops are simultaneously exposed to these stress factors on the field. The response and level of tolerance to both stress factors, however, depend on the crop's genetic and nutritional status. The level of infection or infestation is determined by the cropping system and soil nutrient status. The induction of defense mechanisms by plants in response to pathogenic attack is dependent on environmental conditions like plant nutrient status. It means that there is a complex signaling network with crop nutrition that enables the plants to recognize and protect themselves against pathogens and other environmental stresses. The disease severity could be reduced by adequate crop nutrition due to host nutrient availability, plant composition of secondary metabolites, and the effect on the plant defense mechanisms. Shortages in essential nutrients on their own can predispose plants to attack by pests and pathogens. Therefore, the only sustainable method for growing crops in the face of different environmental stresses is good crop nutrition. A well-fed crop is more resistant to environmental hazards than poorly-fed crop. Though leguminous crops can fix atmospheric nitrogen themselves, the nutritional requirements for healthy crop production are more than just one element. The ability to fix nitrogen, if combined with appropriate crop nutrition will place the plant in a better position to withstand environmental stresses. This chapter discusses some of the different nutrient elements required by leguminous crops and their functions, crop nutrition abiotic stress tolerance, and mechanisms of nutrient-induced resistance in leguminous crops.

**Keywords:** Fertilisers, Legumes, Environmental Stress, Crop health, Crop yield.

\* **Corresponding author Sifau A. Adejumo:** Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria; Tel: +234-803-413-0018; E-mail: sifauadejumo@gmail.com

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

#### **INTRODUCTION**

In grain legume production, biotic stress factors such as insect pest attack and pathological diseases have been reported to be the important constraints limiting grain yield [1]. To increase grain yield in the face of biotic stress, different strategies have been proposed. The most important strategy is adequate plant nutrition. A balanced nutrient supply is a basic requirement to protect plants against all forms of stress [2]. The plant growth rate is proportional to nutrient availability and accessibility. A decline in soil fertility has been found to increase the negative crop response and susceptibility to both biotic and abiotic stress. Poor nutrition impairs crop response and tolerance to stress factors. The low grain yields in legumes have been attributed to poor crop management practices and poor soil fertility [1]. Liebig's "Law of the Minimum (1855) stated that 'The genetically fixed yield potential of crops is limited by the nutrition' [2]. The yield potential of any crop is, therefore, determined by the amount of nutrients supplied and taken up by the plant. The presence and availability of essential mineral elements in the soil, therefore, have a significant impact on the plant's health and determine the plant's response to environmental stresses.

Meanwhile, most farmers do not apply additional nutrients to sole cowpea production due to its ability to fix atmospheric nitrogen. But for greater resistance and enhanced tolerance to environmental stress, the addition of fertilizers is needed to boost cowpea tolerance. In fact, nitrogen itself is needed as a starter dose in areas where soils are poor in nitrogen before nodules begin to fix atmospheric nitrogen [3]. Though, nodulation and N fixation can be inhibited by high field N levels due to the inhibition of nitrogenase activity through a feedback mechanism, but moderate/optimal soil nitrogen level is required for effective nodulation [4]. Besides, in the absence of other nutrients like phosphorous, which is critical to cowpea yield, nitrogen fixation is also strongly affected [5]. Phosphorus is the most limiting soil fertility factor for cowpea production in many tropical soils because it stimulates growth, initiates nodule formation, and promotes rhizobium-legume symbiosis apart from other benefits. It means that cowpea nitrogen-fixing ability might also be affected under P deficiency. Again, it has been observed that under stress, the physiological mineral nutrient demand is always higher than that of normal growth. More carbon and nutrients are needed to be able to carry out the stress-induced metabolic activities and ameliorative processes.

The fixed nitrogen might therefore not be able to support leguminous crops under biotic stress. Appropriate and sufficient fertilization is the key to sustainable crop production, especially under stress. The success of pest attack, though, positively correlates with the plant's nutrient status in some reports [6], but the survival or

#### 132 Advances in Legume Research, Vol. 2

loss encountered is reduced in a well-fed plant. The plant's nutrient status is related to its capacity to ameliorate the negative impacts caused by stress conditions [3, 7]. Best compensatory performance under biotic stress has been reported under proper nutritional management compared to only pest control [6]. Improvement of phosphorus, nitrogen, potassium (P, N, K) and cation contents in the topsoil has been found to increase cowpea grain yield under biotic stress compared to unfertilized fields with pest control [1]. Malnutrition, therefore, predisposes crops to biotic stress. The rate of recovery is also affected or delayed in the absence of balanced nutrition for crops.

Beneficial mineral nutrients should, however, be able to promote growth and yield under stress and strengthen the natural resistance of plants against abiotic and biotic stresses. Apart from mineral nutrients, water is also an essential component of crop nutrition. Legumes like other crops also require more moisture for N fixation. Water is required to export N products from the nodules to the rest of the plant. In the absence of water, N products build up in the nodule and inhibit further fixation by the nodules. With regard to response to biotic stress, lack of water has also been reported to promote insect attack compared to well-watered plants. For instance, aphid performance was found to be the highest in crops subjected to moderate drought stress [8]. Similarly, extreme moisture stress can inhibit nodule initiation or cause nodule shedding in some legume species. It can also reduce N fixation potential by depriving the nodules of sufficient oxygen for rhizobial respiration. Soil nutrient availability and water status can, therefore, have a strong influence and diverse effects on how legumes respond to biotic stresses. The importance of macro and micro-elements in the performance of leguminous crops and tolerance to biotic stresses are discussed in this chapter.

#### **CROP NUTRITION AND BIOTIC STRESS RESPONSES**

There are strong interactions between nutrients and other environmental factors, especially, biotic factors. A balanced nutrient supply is the basic requirement to protect plants against all forms of stress. The importance of individual nutrients for maintaining or promoting plant health and growth has been well documented [7]. The level of crop response to biotic stress is dependent on its nutrient status, the type of nutrient available to such crop, and the quantity. It has been observed that an adequate supply of mineral elements in the growth medium is paramount, for plants to survive under different environmental stresses including biotic stress [7, 9]. The growth and survival of leguminous crops under biotic stress are also dependent on the soil nutrient status and ability to fix atmospheric nitrogen effectively. The increased nutrition enables the plants to repair and compensate for the damage caused by insects or pathogens without a reduction in yield. The

# **Physiological Response of Legumes to Combined Environmental Stress Factors**

Ifedolapo O. Adebara<sup>1,\*</sup>

<sup>1</sup> Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

Abstract: Legumes are considered the second most important source of food after cereals, and their production can be affected by abiotic and biotic stresses. The incidence of biotic and abiotic stress conditions resulting from climate change is expected to increase in the future and may affect legume production drastically. Abiotic stresses could result in escalated biotic stress occurrence. Although responses to abiotic and biotic stress differ in most cases, combined abiotic and biotic stress responses could be expressed in synergistic or opposing forms. In view of the impending escalation in climate change, responses of legumes to stressful environments are expected to vary among crops. However, collective information on combined biotic and abiotic stress in legumes is not readily available. This paper seeks to gather available information on the responses of legumes to biotic, abiotic, and combined stress with a focus on physiological responses. This review will, therefore, help in providing information and encourage further research into combined stress factors in legumes.

**Keywords:** Biotic stress, Abiotic stress, Combined stress, Physiological responses, Climate change, Legume production.

#### **INTRODUCTION**

Legumes are the largest source of vegetable protein in human diets and livestock feed, they therefore, perform a very important function in reducing protein malnutrition as described by Dita *et al.* [1] and Choudhary *et al.* [2]. Legumes can be either grain or forage, whereby grain legumes include soybean (*Glycine max*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea*), cowpea (*Vigna Unguiculata*), pea (*Pisum sativum*), common bean (*Phaseolus vulgaris*) and pigeon pea (*Cajanus cajan*) amongst others. Meanwhile, forage legumes include alfalfa (*Medicago sativa*), and birds foot trefoil (*Lotus japonicus*), both of which

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

<sup>\*</sup> **Corresponding author Ifedolapo O. Adebara:** Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria; Tel: +234 912 357 0150, +234 810 005 8524; E-mail: ifedolapobabalola@gmail.com

#### Physiological Response of Legumes

have been used as model legume crops for decades. The production of legumes is, however, limited by various biotic and abiotic factors. Abiotic factors, such as drought, extreme temperatures, mineral nutrient imbalances, and salinity are the most important stress factors affecting legumes. Biotic factors such as fungi, viruses, bacteria, nematodes, insects, and weeds are very limiting to the growth and productivity of both grain and forage legumes. Abiotic and biotic stress factors individually severely affect crop yield in general and a combination of these factors can also be detrimental [3].

Many of these biotic and abiotic stress factors are common to all legumes; however, the incidence and severity of these stress vary according to leguminous crop species and the location in which they are grown [1]. These factors manifest in altering physiological activities and metabolism in plants resulting in eventual yield loss of up to 90% or total yield loss depending on the intensity and severity of the stress factor imposed on plants. In the field, these stresses rarely occur in isolation, but they often take place in varying combinations simultaneously [4]. The stress could be in abiotic-abiotic stress combinations or abiotic-biotic stress combinations. Current evidence suggests differences and uniqueness in the plant's ability to respond to a combination of stress as compared to individual stress responses [3]. Furthermore, these stress factors usually affect and influence crop's responses physiologically, morphologically, biochemically, and molecularly, and result in a completely new physiological state in certain cases where the stress has ended, especially when tolerance has been exceeded [5].

Recent predictions have reported expected changes in climatic conditions, predicting sporadic rainfall patterns, warmer temperatures and global warming which will bring about increased incidence of biotic and abiotic stress. Such environmental stress conditions may in turn limit agricultural productivity [6 - 10]. According to Mittler [11], Atkinson and Urwin [12] and Suzuki *et al.* [13] influences of these negative conditions on plants may trigger additive, negative, or interactive effects. In this case, the interactions between various abiotic and biotic stresses may cause significant growth and yield outcomes. On the other hand, abiotic stress can enhance the susceptibility of the crop to pathogen attack while these pathogens may alter the crop's response to abiotic stress factors [3]. Therefore, as this chapter indicates, studying the interactions between stresses and the variations in crop response, particularly to combined stress effects remains pivotal for breeding purposes and developing strategies for stress-tolerant crops.

#### **BIOTIC STRESS IN LEGUMES**

#### **Fungal Diseases**

The major biotic stress affecting legumes is fungal diseases even though other biotic stresses (viruses, nematodes, insects, bacteria, and weeds) can still result in drastically reduced legume growth and productivity [1]. Fungi, which are biotrophic pathogens cause severe foliar diseases which serve as major constraints in legume production [14]. Fungal foliar diseases that are important affecting legumes are rusts, powdery mildews, and downy mildews. Rust species infecting grain and forage legumes belong to the genus Uromyces such as Uromyces appendiculatus in common bean, U. ciceris-arietini in chickpea, U. vignae in cowpea and U. striatus mostly infecting alfalfa. Other rust species belonging to other genera that affect legumes include *Phakopsora pachyrhizi* often found in soybeans, Puccinia arachidis of groundnut [15] and Asian rust that also infects soybean [16]. Other fungal diseases, such as necrotrophic fungal diseases comprise Ascochyta blight and Botrytis gray mildew which are most common in chickpeas [17]. Soil-borne pathogens known to attack legume crops causing drastic effects in seedlings and adult plants of chickpeas, soybeans, and lentils comprise species of Fusarium, Pythium, and Rhizoctonia [18].

#### Viral Plant Diseases

Among the many plant pathogens, viral diseases that affect legumes are of particular importance in crop species grown in the subtropical and tropical regions [19]. The viral diseases are transmitted either through seeds or vectors and can also be transmitted by means of mechanical inoculation in cases where induced infections are needed for indexing or research purposes. Legume viruses that are commonly transmitted through seeds include Bean Common Mosaic Virus (BCMV), Cucumber Mosaic Virus (CMV), Alfalfa Mosaic Virus (AMV), Sovbean Mosaic Virus (SMV), Peanut Mottle Virus, Peanut Stripe Virus, Bean Yellow Mosaic Virus (BYMV) and Bean Golden Mosaic Virus (BGMV). These viruses are considered the most limiting viral pathogens in bean production, especially in the Caribbean and also in some parts of Central America. Covne (year) reported that these viruses resulted in drastic yield losses of up to 100% in many crop fields where they occurred. Other important legume viruses include Groundnut Rosette, which is of high importance in Africa, chickpea stunt occurring both in Africa and Asia [20], pigeon pea sterility mosaic virus, pea bud necrosis virus, and Tobacco streak virus which mainly affects groundnuts [21, 22].

#### **SUBJECT INDEX**

#### A

Abiotic stress(s) 15, 17, 130, 131, 134, 136, 139, 142, 143, 147, 148, 150, 151, 152 effects 151 tolerance 130 Acid(s) 135, 147, 150, 151, 152 abscisic 151 allantoic 150 ascorbic 150 jasmonic 147, 152 orthosilicic 135 salicylic 152 Activation 134, 137, 138 enzyme 137, 138 Activities 22, 28, 40, 50, 66, 96, 131, 138, 146, 149 anthropogenic 96 enzymatic 138 glutamate synthase enzyme 149 metabolic enzyme 149 nitrate reductase 138 nitrogen-fixing 138 nitrogenase 131, 149 parasitic 28 photosynthetic 22, 66, 146 protease enzyme 50 viral polymerase 40 Adenosine triphosphate (ATP) 2, 137 African cassava mosaic virus 43 Agricultural 10, 14, 26, 28, 38, 39, 84 crops 26, 28, 84 ecosystems 84 industry 38, 39 sustainability 10, 14 Alfalfa mosaic virus (AMV) 2, 3, 43, 144 Application 22, 105, 106 foliar 105, 106 fungicide 22 Aspergilus fumigatus 51

#### B

Bacillus thuringiensis 122 BCMV 76, 77 diseases 76 resistance genes 77 Bean 3, 6, 64, 65, 73, 76, 144 common mosaic virus (BCMV) 64, 65, 73, 76, 144 golden mosaic virus (BGMV) 3, 6, 144 Beet western yellow virus (BWYV) 3 **Biological pesticide applications 74** Biotic stress 1, 4, 8, 9, 10, 14, 111, 131, 143, 152 factors 1, 4, 9, 10, 14, 111, 131, 143, 152 resistance 1.8 Biotic stressors 14, 17, 19, 29 **BPMV** infection 25 Breeding 1, 9, 10, 118 cycles 10 methods 1, 9, 10 substrate 118 techniques 9 Broad Bean 3, 6 mosaic virus (BBMV) 3, 6 wilt virus (BBWV) 3 Brome mosaic virus (BMV) 43. 50

#### С

Cell wall degrading enzymes (CWDEs) 42 Chlorosis 24, 29, 66, 70 severe systemic 24 Conditions 2, 37, 38, 39, 86, 90, 96, 116 fluctuating climate 116 growth-inhibiting 2 hypoplasia 38 Cowpea 16, 19, 20, 21, 24, 25, 26, 27, 131 aphid-borne mosaic virus (CABMV) 24, 27 cropping system 20 mosaic virus 24, 25

Phetole Mangena & Sifau A. Adejumo (Eds.) All rights reserved-© 2023 Bentham Science Publishers

#### 162 Advances in Legume Research, Vol. 2

production 16, 19, 20, 21, 24, 26, 131 rust 21 viruses infect 24 Cowpea plants 20, 23, 26, 27, 152 infected 20 **CRISPR 9, 124** associated proteins 9 system 124 Crop(s) 1, 2, 6, 7, 8, 9, 42, 65, 68, 72, 73, 83, 84, 85, 89, 90, 91, 92, 104, 106, 111, 112, 114, 117, 118, 121, 123, 130, 132, 136, 143, 145, 152 agronomic 8 cereal 8, 85 damage 114, 117 diseases 8 engineered 106 horticultural 73 gene transformation 123 genotype 121 growth 7, 111, 112, 118 health 130 infected 72, 73 insects damage 145 nonleguminous 42, 65 stress-tolerant 143 virus-infected 68 Crop plants 4, 8, 10, 47, 123, 134, 146 infected 146 stressed 134 Crop production 1, 7, 15, 16, 83, 84, 111, 112, 131, 139 sustainable 131 systems 15, 16 Crown gall diseases 38 Cucumber mosaic virus (CMV) 24, 43, 64, 65, 72, 73, 74, 75, 144, 146

#### D

Damage 26, 27, 29, 77, 83, 84, 85, 86, 87, 91, 92, 112, 119, 120, 121, 135, 146, 149 economic 83, 87 morphological 146 oxidative 135, 149 Defence 66, 67, 99, 135 antioxidant 135 related proteins (DRPs) 67 Deficiency, nutrient 134 Detection, fungal disease 53

#### Mangena and Adejumo

Devices 90, 91 efficacious 91 Disease(s) 2, 3, 7, 14, 17, 19, 20, 21, 22, 23, 25, 38, 39, 42, 48, 65, 133, 146, 151 causing pathogens 14, 17 symptoms 7, 25, 42 devastating 22 lesion 146 DNA 41, 45, 46, 71, 100 amplified 46 bacterial 41 barcoding 100 Drought 15, 17, 19, 111, 112, 118, 124, 130, 143, 147, 148, 149, 150, 151, 152 combined 151 stress 111, 148, 150, 151, 152 terminal 149

#### Е

Effective cross-pollination 8 Effector 42, 135 proteins 42 triggered immunity (ETI) 135 Effects 3, 143 harmful 3 interactive 143 Electrophoresis 41, 45, 52 Elevated temperature stress 149 ELISA 41. 46. 47 based detection 47 double-sandwich 46 Environmental 14, 15, 19, 130, 131, 132, 134, 135, 139, 147, 152 hazards 130 stresses 14, 15, 19, 130, 131, 132, 134, 135, 139, 147, 152 Enzymatic antioxidant defense 150 Enzyme(s) 6, 38, 41, 42, 46, 49, 67, 71, 123, 134, 137, 138 antioxidant 134 chloroplast 71 detoxifying 138 hydrolytic 38, 49 linked immunosorbent assays 41, 46 proteins 42 toxic 6 Eye irritation 123

Subject Index

#### F

Factors 4, 95 interacting 95 physiographic 4 Fatty acids 53 phospholipid-derived 53 Food 16, 26, 42, 86, 105, 106, 117, 118, 142 absorption 42 Fungal 38, 41, 42, 144, 146 foliar diseases 144 infections 146 plant pathogens 38, 41, 42 Fungal diseases 19, 134, 144 necrotrophic 144 Fungi 1, 2, 6, 7, 14, 15, 19, 20, 22, 28, 29, 38, 42, 43, 134, 143, 144, 145 hemi-biotrophic 134 mycorrhizal 6 saprophytic 38 Funnel web spider syndrome 99

#### G

Gas chromatography (GC) 53 Gene 4, 51, 123 expression 4, 51 transformation 123 Genome editing technique 124 Glutamine synthetase (GS) 135 Glycoproteins 41, 53

#### Η

Herbivore-induced plant volatiles (HIPVs) 8, 9 Homeostasis 135 Hypersensitive 45

#### I

Immune signaling 135 Immunoblotting 46 Immunofluorescence 46 Infection 24, 38, 39, 41, 65, 73, 74, 76, 145, 146 host cell 41 natural 65 nematode 146

phytopathogenic 39 reducing viral disease 74 viral 24, 38, 73, 76, 145 Infectious 7, 41, 67 diseases 7 microorganisms 41 pathogens 67 Infestation of weeds 145 Influence, moisture stress 19 Insect 9, 101, 117, 118 herbivores 9, 101, 117, 118 Insect pests 2, 3, 4, 101, 102, 104, 105, 111, 112, 113, 114, 116, 119, 122, 123, 124 combat 122 managing 123 sucking 123 Insecticides 8, 9, 28, 69, 74, 75, 101, 105, 106, 121, 122 residual liquid 106 Inserting DNA bases 124 International committee on taxonomy of viruses (ICTV) 43, 64, 65

#### K

Koch's postulate method 48

#### L

Larval hatching 114 Legume(s) 7, 65, 144 cultivated 65 viruses 7, 144 Legume crop 39, 104 diseases 39 productivity 104 Legume growth 15, 64, 65, 144, 148, 152 reduced 144 reducing 65 Leguminous 39, 42, 130, 146 agronomic crops 42 crop plants 146 crop production 39, 130 Lesions, necrotic 23, 24, 74

#### Μ

Magnaporthe oryzae 38 Magnesium deficiencies 150

#### Advances in Legume Research, Vol. 2 163

#### 164 Advances in Legume Research, Vol. 2

Mechanisms 123, 134 efficient compensatory 134 nontoxic 123 Metals, heavy 148 Metamorphosis 117, 121 Methods, immunological 51 Microbes 6, 7, 38, 122, 147 cause deterioration 38 nitrogen-fixing 6 Microbial pesticides 122 Mineral deficiency 150 Mosaicdistinct 66 Mosaic virus 43, 50, 67 brome 43, 50 cauliflower 43

#### Ν

Necrotic yellow vein virus 41 Nematodes 1, 2, 3, 14, 15, 17, 28, 29, 65, 143, 144, 145, 146 parasitic 1, 2 pea cyst 146 pests 28 Nervous necrosis virus 41 Next-generation sequencing (NGS) 47, 48 NGS method 48 Nitrogen 2, 6, 131, 137, 138, 139, 146 fixation 131, 137, 138, 139 fixing bacteria 2, 6, 146 Nitrogenase 139, 151 Nucleic acid(s) 44, 45, 46, 47, 49, 53, 71, 73, 136, 137, 138 based methods 44, 46, 53 extraction methods 47 metabolism 138 synthesis 138 Nucleotide(s) 45, 47, 50 triphosphatase 50 Nutrients 6, 132, 134, 139, 145 inorganic 6 mineral 132, 134, 139, 145 sucking phloem 6 Nutrition 131, 134 Nutritional disorders 149

#### 0

Obligatory carnivores 101

Odontoglossum ringspot virus 65 Oils, vegetable 123

#### P

Parasitic weeds 14, 26, 27, 29, 145 Pathogen-associated molecular patterns (PAMP) 135 PCR 46 amplification 46 assays 46 single-strand conformation polymorphism 46 PCR-based 41, 45 detection 45 techniques 41 Peanut 144 mottle virus 144 stripe virus 144 Pectinases 38, 42 Pest(s) 6, 7, 8, 14, 15, 65, 66, 83, 84, 86, 87, 96, 104, 106, 112, 114, 117, 121, 122, 133, 134 agricultural 114 arthropodous 6 destructive 83 economic 7 harmful 104 infestations 106, 133, 134 insecticide-resistant 8 Pest damage 84, 96, 118 vertebrate 84 Pesticides 9, 67, 71, 91, 96, 105, 121, 122, 123 biochemical 122, 123 Photosynthesis 71, 73 process 71 reduction 73 Phytophthora infestans 42 Plant(s) 15, 20, 28, 44, 45, 46, 48, 51, 65, 67, 71, 73, 74, 75, 76, 77, 101, 122, 130, 133, 134, 136, 144, 145, 149, 151 debris 67, 75 defense mechanisms 130 metabolism 122 nitrogen fixing 136 nitrogenase activity 149 nutrients 15, 133 ornamental 48 parasitic 145

#### Subject Index

parasitic nematodes (PPNs) 28, 151 pathogens 20, 44, 46, 51, 144 protein 45 stressed 134 transgenic 77 vegetation 101 virology 65 virus-infected 71, 73, 74, 76 Plant diseases 38, 47, 105 bacterial 38 transmitting 105 Plant infections 39, 41 viral 39 Polymerase chain reaction (PCR) 41, 45, 46, 47 Potato dextrose agar (PDA) 40 Proteases 38, 50, 146 cysteine 50 Protection, environmental 10 Proteins 2, 15, 16, 17, 18, 41, 42, 44, 47, 50, 51, 52, 53, 67, 70, 123, 136, 137, 142, 151 enzymatic 2 enzymes 41 heat-shock 151 malnutrition, reducing 142 mass spectrometry 52 multiple defence-related 67 mycelium 41 nucleocapsid 70 protoxin 123

#### R

Reactive oxygen species (ROS) 49, 71, 134, 150, 151 Reproduction, sexual 8 Reproductive system disorders 123 *Rhizoctonia solani* 19 RNA 50, 123 capping methyltransferase 50 interference (RNAi) 123

#### S

Saccharomyces pathogens 51 SDS-PAGE 52 Seed(s) 3, 25 borne mosaic virus (SBMV) 3

infected 25 Silicon-induced resistance 134 Single-stranded RNA virus 24 Soil 24, 131 fertility 131 water stress 24 Soybean mosaic virus 24, 25, 43, 144 Spiders, arthropods 96 Splashing water droplets 24 Stomatal resistance 151 Streptomyces 7 Streptomycin 38, 48 Stress 2, 4, 130, 131, 132, 133, 134, 137, 143, 147, 148, 149, 150, 151, 152 chilling 149 cold 148, 149, 150 heat 149, 151 nutrient 133 osmotic 149 oxidative 134, 149 ozone 152 responses 143, 148, 152 signalling responses 137 Stress combinations 152 abiotic 152 Stress conditions 15, 132, 143 environmental 143 Stress factors 1, 4, 15, 130, 131, 139, 143 abiotic 15, 143 environmental 139 Sudden death syndrome (SDS) 28 Symbiotic nitrogen fixation (SNF) 149 System 4, 15, 138 cereal production 15 constitutive defense 4 photosynthetic electron transport 138

#### Т

TMV infection 66 Tobacco 41, 43, 64, 65, 66, 67, 144 mosaic virus (TMV) 41, 43, 64, 65, 66, 67 ringspot virus 43 streak virus 144 Transcriptional activator-like effector nucleases (TALENs) 124 Transformation, indirect-vector mediated 10

#### V

Viral 24, 37, 39, 43, 64, 66, 70, 75, 144 diseases 24, 37, 39, 66, 70, 75, 144 morphology 64 pathogen, seed-borne 43 plant diseases 144 Virus(s) 1, 2, 6, 7, 14, 24, 39, 41, 43, 47, 51, 64, 65, 70, 77, 144, 145 co-infecting 47 detrimental 7 legume-infecting 65 plant-infecting 70 potato 43 Virus infection 66, 68, 75 tobacco mosaic 66

#### W

Water stress 66, 150

#### Х

Xanthomonas axonopodis 23, 145



#### Phetole Mangena

Phetole Mangena is a senior lecturer at the University of Limpopo and earned his Ph.D. in botany from this University in September 2019. He published numerous research articles on in vitro and in vivo genetic improvement and mutagenic breeding of soybean and other leguminous crops. He has also received several awards, including the NRF emerging researcher award in the National System of Innovation of South Africa. He also does academic writing, having published a book about indirect gene transfer, Plant Transformation via Agrobacterium tumefaciens and edited two more books in legume research. He continues contributing to the field of plant physiology and biotechnology, mentoring aspiring scientists and serving as editor for Frontiers in Agronomy, Frontiers in Plant Science, Plant Science Today, Research Journal of Biotechnology and Journal of Experimental Biology and Agricultural Sciences.



Sifau A. Adejumo

Sifau A. Adejumo is an associate professor and researcher in the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria. She obtained a Ph.D. in agriculture (with specialization in environmental crop physiology) from the same university in 2010. She teaches courses at both undergraduate and postgraduate levels and she has supervised many undergraduate and postgraduate students' projects. Her research works focus on the innovative uses of different organic amendments and biochar for stress amelioration in crop, soil fertility improvement, adaptability to climate change and soil remediation for crop yield improvement. She has worked in different capacities with local, state and federal government of Nigeria and has won several awards and fellowships to her honour. She has attended and presented academic papers both within and outside Nigeria and published many research articles both in the conference proceedings and peer reviewed journal at local and international levels. She is a member of many academic bodies/societies.