Soil Biology

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Ajit Varma *Editors*

Organic Amendments and Soil Suppressiveness in Plant Disease Management

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Preface

In view of the rising public concerns about economic and ecological consequences of agricultural chemicals, the emphasis on crop improvement strategies has gradually been shifting from chemical to non-chemical approaches for sustainable agriculture. Soil amendment is one such approach that can play a significant role in building up soil fertility and improving soil health for sustainable agriculture. Various research reports have convincingly established the role of organic amendments in improving plant growth, health, and yield. In addition, organic amendments contribute to enhancing soil suppressiveness.

Soil suppressiveness is often attributed to activity of soil microorganisms or microbial metabolites. However, physicochemical properties of soil, including pH, organic matter, and clay content, can also contribute to the suppression of plant diseases directly or indirectly through their influence on soil microbial activity. It is therefore important to know the influence of soil physicochemical properties on disease suppression. Although one set of physicochemical attributes of soil considered as suppressive for a disease may be conducive for other one. It is therefore equally important to understand the physicochemical characteristics of soil which are unfavourable to the specific disease development. It has also been established that some of the soil-borne plant diseases can be effectively managed through organic amendments. It is, therefore, equally imperative to understand the relationship between organic amendments and soil suppressiveness. Despite being a very significant area from the view point of plant disease management through sustainable means, literature is scanty on the topic. The main objective of the present volume *Organic Amendments and Soil Suppressiveness in Plant Disease Management* is to make efforts to fill this gap by synthesising the literature on various aspects of organic amendments and soil suppressiveness in order to utilise potential of these phenomena more effectively and efficiently in sustainable agriculture.

The present volume has four parts with a total of 25 chapters. Part I deals with general paradigms and mechanisms of soil suppressiveness, comprising eight chapters. Parts II and III focus on concepts in plant disease management involving microbial soil suppressiveness and organic amendments, respectively. Part IV elaborates various combinatorial approaches in plant disease management. Each chapter in these parts provides an overview of the topic, current knowledge and recent developments, conclusions, and directions for future research following an in-depth and critical analysis of the literature.

In Chap. 1, George. M. Kariuki, Lilian K. Muriuki, and Emma M. Kibiro discuss how suppressive soils affect or influence plant pathogens' suppression in the soil and how they contribute to agricultural productivity. Chaney C. G. St. Martin in Chap. 2 provides a detailed account of current knowledge on enhancing soil suppressiveness using compost and compost tea, along with predictors and mechanisms of disease suppression and factors affecting the efficacy of compost and compost tea. Furthermore, the potential application of molecular tools for better understanding the relationship between microbial properties of compost and compost tea and soil suppressiveness is highlighted and core areas for research identified in Chap. 2. In Chap. 3, D. P. Singh reviews the information on research done on soils and crop health of rice–wheat system under conservation agriculture. Agronomic strategies for developing disease-suppressive soils for improved soil and plant health and productivity as well as for environmental benefits are discussed in Chap. 4 by R. S. Yadav, Jitendra Panwar, H. N. Meena, P. P. Thirumalaisamy, and R. L. Meena. In Chap. 5, Prashant P. Jambhulkar, Mahaveer Sharma, Dilip Lakshman, and Pratibha Sharma discuss natural mechanisms of soil suppressiveness against diseases caused by *Fusarium*, *Rhizoctonia*, *Pythium*, and *Phytophthora*. The pea footrot disease symptoms and assessment, molecular basis of pea footrot disease, and the potential role of agricultural soil health indices in pea footrot disease suppressiveness are discussed by Ebimieowei Etebu in Chap. 6. Subsequently, Chap. 7 contributed by Phatu W. Mashela, Zakheleni P. Dube, and Kgabo M. Pofu provides the dosage model as an alternative strategy in managing plant parasitic nematodes with specific reference to addressing efficacy, phytotoxicity, and inconsistent result issues of phytonematicides. Chapter 8 by Silvana Pompeia Val-Moraes focuses on recent progress towards unravelling the microbial basis of suppressive soils. In Chap. 9, Mona Kilany, Essam H. Ibrahim, Saad Al Amry, Sulaiman Al Roman, and Sazada Siddiqui present recent advances and findings regarding the role of beneficial microbes in the pythium damping-off disease suppression and the biological aspects highlighting the mechanisms of action of biocontrol process. Interaction of rhizobia with soil suppressiveness factors has been discussed at length by Kim Reilly in Chap. 10. In subsequent chapter, an overview of the biocontrol potential of opportunistic as well as AM fungi on the growth and improvement of various crop plants and population of plant parasitic nematodes in different pathosystems has been provided by Mohd. Sayeed Akhtar, Jitendra Panwar, Siti Nor Akmar Abdullah, and Yasmeen Siddiqui. This chapter also focuses on the cost-effective technologies used for the mass propagation of opportunistic fungi and AM fungi and their ample application in the expansion of practical control system desired for the sustainable agricultural practices. In Chap. 12, different aspects of microbial soil suppressiveness and their impact on wilt disease have been discussed in detail by M. K. Mahatma and L. Mahatma. Chapter 13 by Erin Rosskopf, Paula Serrano-Pérez, Jason Hong, Utsala Shrestha, María del Carmen Rodríguez-Molina, Kendall Martin, Nancy Kokalis-Burelle, Carol Shennan, Joji Muramoto, and David Butler summarises the research that has been conducted on anaerobic soil disinfestations (ASD) around the world and to suggest research areas that are of interest and importance for the future. Topics of their discussion also include the impact that amendment choice and temperature have on generating anaerobic conditions; how the process of ASD changes soil chemistry; changes in the microbial community as a result of ASD and the role microbes play in anaerobicity; and what is currently known about creating a disease-suppressive soil using this method. Chapter 14 by Yasmeen Siddiqui, Yuvarani Naidu, and Asgar Ali highlights the potentiality of harnessing microbial diversity utilising compost and compost teas for mitigation of fungal diseases of fruits and vegetables in an eco-friendly manner. Yurdagul Simsek-Ersahin in Chap. 15 provides an overview of the current understanding of the influence of vermicompost products, solid or liquefied, on *fusarium* diseases. In Chap. 16, Christel Baum, Bettina Eichler-Löbermann, and Katarzyna Hrynkiewicz provide an overview on the causal agents of suppression of fusarium wilt evaluating the quality of different organic amendments. Further it aims to facilitate a selection and optimisation of the use of organic amendments in the arable management by reviewing the actual state of knowledge. In Chap. 17, Sazada Siddiqui, Saad Alamri, Sulaiman Alrumman, Mukesh K. Meghvansi, K. K. Chaudhary, Mona Kilany, and Kamal Prasad discuss the role of micronutrients, which can lead to a less disease-favourable environment and increase host plant resistance. The chapter carries out a critical analysis of various factors responsible for the suppression of certain plant fungal diseases due to micronutrients and determines key areas where sincere research efforts are still needed to develop strategies for manipulating micronutrient application in such a way that it could be more efficiently utilised in managing soil-borne plant fungal diseases. L. Grantina-Ievina, V. Nikolajeva, N. Rostoks, I. Skrabule, L. Zarina, A. Pogulis, and G. Ievinsh in Chap. 18 provide an analysis of the impact of organic amendments, i.e. green manure and vermicompost on the soil microorganisms and plant growth and health in conditions of organic agriculture of Northern temperate climate. In Chap. 19, Henok Kurabachew discusses the impact of silicon amendment on suppression of bacterial wilt caused by *Ralstonia solanacearum* in Solanaceous crops. In Chap. 20, various facets of suppression of soil-borne plant pathogens by cruciferous residues have been discussed by Ritu Mawar and Satish Lodha. In Chap. 21, Santiago Larregla del Palacio, María del Mar Guerrero Díaz, Sorkunde Mendarte Azkue, and Alfredo Lacasa Plasencia critically review the mechanisms involved in disease suppression and the organic amendment management strategies for the control of protected pepper crops' soil-borne diseases and soil fatigue. Chapter 22 by David Ruano-Rosa and Jesús Mercado-Blanco provides a brief overview on research efforts devoted to the use of biological control agents (BCAs) and organic amendments (OAs) against soil-borne diseases within integrated disease management strategies. More specifically, this chapter focuses on the ad hoc combination of BCAs and OAs and discuss aspects such as how these approaches may influence soil microbial communities or the suitability of using OAs as carriers to develop more stable and effective formulations of BCAs. Chapter 23 by Mohammad Haneef Khan, M. K. Meghvansi, Rajeev Gupta, K. K. Chaudhary, Kamal Prasad, Sazada Siddiqui, Vijay Veer, and Ajit Varma highlights the potential of individual and combined approach of vermiwash and AM fungi with a particular emphasis on understanding the possible underlying molecular mechanisms involved in the suppression of plant diseases. Chapter 24 by Massimo Pugliese, Giovanna Gilardi, Angelo Garibaldi, and Maria Lodovica Gullino focuses on the use of organic amendments, compost in particular, and soil suppressiveness for the management of diseases of vegetable and ornamental crops. In Chap. 25, a study conducted by Yohichi Matsubara, Jia Liu, and Tomohiro Okada on suppression of *fusarium* crown rot and the changes in free amino acid contents in mycorrhizal asparagus plants with NaCl treatment is discussed in order to clarify the mechanisms of disease tolerance.

The editors would like to express sincere gratitude to all the contributors for submitting their work and timely responding to all the post-submission editorial queries. We have received numerous insightful and constructive inputs from the researchers all across the world on this subject while editing this book for which we are sincerely grateful to them. Dr. Mukesh K. Meghvansi takes this opportunity to express his deep sense of gratitude to Dr. Vijay Veer, Director, Defence Research Laboratory, Tezpur, for his constant support, encouragement, and guidance. Dr. Meghvansi wishes to thank Mrs. Manju Meghvansi (wife) and Miss Lakshita Meghvansi (daughter) for their unconditional love, patience, understanding, and moral support while editing this volume. Last but not the least, we thank all the staff members of Springer Heidelberg, especially Dr. Jutta Lindenborn, project coordinator (Springer Books—Life Sciences and Biomedicine), for their critical evaluation, constant support, and encouragement.

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Contents

Part I
Soil Suppressiveness: Paradigms and Mechanisms

Chapter 1
The Impact of Suppressive Soils on Plant Pathogens and Agricultural Productivity

George M. Kariuki, Lilian K. Muriuki, and Emma M. Kibiro

1.1 Introduction

Soil is a key element of agricultural production, which comprises of complex blend of organic and inorganic matter, including different species, the majority of which have not been described. A number of the organisms are pests that result in important crop losses as others carry out environmental activities such as aeration, biological pest control, drainage, and water and nutrient cycling. Soil is the foundation of sustainable agriculture and provides the physical support upon which majority of other human activities rely on (Singh 2013).

Agricultural soils that are suppressive to soilborne plant pathogens exist all over the world (Weller et al. 2002), and the biological basis of suppressiveness has been depicted for majority of the soils. The suppressive soil concept was initially introduced by Menzies (1959) who used the term in the description of the soils that inhibited *Streptomyces* potato scab (Weller et al. 2002). Suppressive soils have been referred to as soils in which there cannot be establishment or persistence of pathogen (Shurtleff and Averre 1997), there can be establishment of the pathogen but it causes little or no damage, or there can be establishment of the pathogen and development of disease but the disease is less significant, even though the pathogen may persist in the soil or soils in which some diseases are inhibited because of the presence, in the soil, of microbes that act antagonistically against the pathogen or pathogens (Baker and Cook 1974). On the contrary, conducive soils are ones in which disease occurs readily. Pathogen suppression is termed as the inhibition of saprophytic survival or growth of the pathogen in the soil, while disease

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suppression is the inhibition of the parasitic growth of the pathogen (Simon and Sivasithamparam 1989).

Soil suppressiveness is associated with the level of fertility, types, and numbers of soil organisms, as well as nature of the soil texture and drainage. Mechanisms through which soilborne pathogens are affected by rhizosphere microorganisms have been keyed out and include consumption of pathogen stimulatory compounds, antibiotic compound production, direct parasitism, (micro)nutrients competition, as well as production of lytic enzymes (Lugtenberg and Kamilova 2009). Suppressive soils are essential in agricultural production since severity or occurrence of disease is less than expected for the dominating environment or in comparison to that in surrounding soil that reciprocally results in higher crop yields. Suppressive soils are the best natural examples in which the natural microflora efficaciously offers protection to plants against pathogens. Various pathogens for which suppressive soils have been demonstrated include fungi such as *Pythium splendens* (Kao and Ko 1983), *Fusarium oxysporum* (Alabouvette et al. 1993), *Gaeumannomyces graminis* var. *tritici* (Hornby 1998), *Aphanomyces euteiches* (Persson et al. 1999), *Phytophthora cinnamomi* (Ko and Shiroma 1989), *Thielaviopsis basicola* (Stutz et al. 1986), *Phytophthora infestans* (Andrivon 1994), *Pythium ultimum* (Martin and Hancock 1986), *Plasmodiophora brassicae* (Murakami et al. 2000), and *Rhizoctonia solani* (Lucas et al. 1993); nematodes such as *Heterodera schachtii*, *H. avenae*, *Criconemella xenoplax*, and *Meloidogyne* spp.; and bacteria such as *Ralstonia solanacearum* and *Streptomyces scabies* (Haas and Défago 2005).

The main objective of this chapter is to describe how suppressive soils affect or influence plant pathogen suppression in the soil and how they contribute to agricultural productivity. We have discussed different types of soil suppressiveness and factors that influence them. Different types of suppressive soils which include fungi-suppressive soils, bacteria-suppressive soils, and nematode-suppressive soils have also been discussed highlighting the contribution of these types of soils to agricultural productivity.

1.2 Impact of Soil Health on Agriculture

Soil health is termed as the soil's capacity to function as a critical living system, within ecosystem and land-use boundaries, in order to sustain productivity of animals and plants, enhance or maintain air and water quality, as well as enhance animal and plant health. Soil health is critical to crop production. Since it is fragile and finite, soil is an important resource that needs special care from its users. Majority of crop and soil management systems today are not sustainable. On the one hand, overutilization of fertilizer has resulted in nitrogen deposition, which is a threat to the sustainability of an approximated 70 % of nature (Hettelingh et al. 2008). On the other hand, in most regions of sub-Saharan Africa, the underutilization of fertilizer entails that soil nutrients exported together with crops fail to be replenished, resulting in the degradation of soil, as well as decrease