Integrated Management of Diseases Caused by Fungi, Phytoplasma and Bacteria

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PREFACE

This volume focuses on integrated pest and disease management (IPM/IDM) and biocontrol of some key diseases of perennial and annual crops. It continues a series originated during a visit of prof. K. G. Mukerji to the CNR Plant Protection Institute in Bari (Italy), in November 2005. Both editors aim at a series of five volumes embracing, in a multi-disciplinary approach, advances and achievements in the practice of crop protection, for a wide range of plant parasites and pathogens. Two volumes of the series were already produced, dedicated to general concepts in IPM and to management and biocontrol of nematodes of grain crops and vegetables.

This Volume deals, in particular, with diseases due to bacteria, phytoplasma and fungi. Every day, in any agroecosystem, farmers face problems related to plant diseases. Since the beginning of agriculture, indeed, and probably for a long time in the future, farmers will continue to do so. Every year, plant diseases cause severe losses in the global production of food and other agricultural commodities, worldwide. Plant diseases are not limited to episodic events occurring in single farms or crops, and should not be regarded as single independent cases, affecting only farms on a local scale. The impact of plant disease epidemics on food shortage ignited, in the last two centuries, deep cultural, social and demographic changes, affecting million human beings, through i.e. migration, death and hunger. The effects of severe epidemics, like those due to *Phytophthora infestans*, are well documented in plant pathology and even in history treatises and literature, and their legacy is still valid today. For this reason a disease causal agent should not only be regarded as a noxious factor limiting crop production or lowering farmers' incomes, but also as a potential threat for the whole food production chain, worldwide. Global epidemics of basic food crops are still a potential issue and a risk that should be considered when planning the welfare of any community, at any scale.

This statement explains the attention devoted to plant diseases, and the efforts deployed for their management and control. As for other disciplines concerning plant protection, we reached today a mature stage in which the optimism initially underlining the widespread use of chemicals and fumigants lent space to a more pragmatic, comprehensive and integrated vision of control. There is, indeed, a general concern about the negative consequences related to the widespread use of chemicals, including not only environmental issues like pollution or contamination, but also the insurgence of resistance in the target organism populations, as well as the farmers' health hazards represented by the use and manipulation of chemicals.

A wide literature already covers several aspects of chemical or biological control, but there is a widespread interest for a more holistic vision of IPM. In this series we tried to fill this gap, aiming at producing an informative coverage for a wide range of cropping systems. Chapters are organized in a first Section dealing with diseases of perennial crops, followed by a second one for annual crops, and a third final Section dealing with advances in DNA application for management, detection and diagnosis, and potentials of endophytes for disease control.

In the first chapter, disease management of stone fruit crops (apricot, cherry, peach, nectarine and plum) is reviewed. These include important diseases like brown rot blossom blight and fruit rot. Research showed the importance of latent infections in brown rot cycle, allowing options for a better disease management. Brown rot is controlled by fungicides, but resistance to benzimidazoles is widespread and appears to be developing further. Cultivars resistant to brown rot, although not yet commercially available, could be helpful for selection of new resistant clones. Other important stone fruit diseases like bacterial canker, Leucostoma canker, powdery mildew and postharvest fruit rots are also reviewed. Both bacterial and Leucostoma cankers cannot be controlled with chemicals, but they are managed using an integrated approach relying on resistance, good horticultural practices and exclusion. Resistance to fungicides in powdery mildew is developing, so the use of spray oils with fungicides is examined. New fungicides are available for the postharvest problems like fruit rots caused by *Monilinia* spp., *Botrytis cinerea* and *Rhizopus* spp., but they need careful management to avoid resistance. The development of new molecular techniques for pathogens identification and their use in disease forecasting and risk management is improving control of stone fruit diseases.

In the second chapter, the major diseases of apples, their management strategies and the problems related to sustainable productions are discussed. Guidelines for sustainable, integrated management of main apple diseases are reviewed, including effective and sustainable tactics. Resistance plays a crucial role in the management of apple diseases, and management problems include the development of fungicide resistance as wel as breakdown of host resistance. Symptoms, causal pathogens, disease cycles and management practices are reviewed for main spring diseases like apple scab, powdery mildew, fire blight and rust diseases. Problems like fungicide resistance and availability of plant resistance are discussed, together with applications of cultural and chemical management with predictive models. Symptoms, disease cycles and management issues are also reviewed for summer diseases, like bitter rot, flyspeck and sooty blotch.

Third chapter follows dealing with the management and ecology of phytoplasma diseases of grapevine and fruit crops. Management of phytoplasma-infected plants focussed on controlling the insect vectors and on roguing infected crops and weeds. Actual management concepts rely on environment compatible measures and on cultural practices. The introduction of disease-resistance genes into cultivated crops togheter with the use of resistance-inducing microorganisms represent potential tools to control phytoplasma diseases.

The fourth chapter deals with citrus diseases caused by *Phytophthora* spp., with reference to root rot, gummosis and brown rot of fruits. Some aspects of the biology and ecology of *P. citrophthora* and *P. nicotianae* are revised, like dissemination, reproduction and epidemiology. The symptomatic diagnosis of main diseases are reviewed, including foot rot or gummosis, fibrous root rot, brown fruit rot and dieback of twigs and leaves. Biological and instrumental diagnosis and laboratory tests for monitoring, sampling and population dynamics studies are revised. Management methods based on interventions on the host-plant, rootstock resistance, grafting as well as sanitary practices in nurseries are shown, with pruning, surgery and cultural practices, i.e. fertilization, irrigation, soil management and weeds control. Chemical control methods are also reviewed, with reference to the use of systemic fungicides for control of trunk gummosis, root rot and brown rot of fruits.

In the following review of biological control and management of chestnut diseases, the main strategies for efficient biological control and management of chestnut blight and ink diseases caused by *Cryphonectria parasitica*, *Phytophthora cambivora* and *P. cinnamomi* are discussed. The cankers of chestnut blight are described, as well as the characters of the different infections caused by *C. parasitica.* The diseases evolution, the spread and effectiveness of hypovirulence are also revised, considering morphology, physiology, presence and transmission of dsRNAs. Chestnut resistance, the role of environmental and other ecological factors in ink disease, including soil microflora, are then discussed. The role of silviculture and biological control strategies for blight and ink disease management are also revised. Improvements in the management of chestnut disease need a better understanding of the ecological dynamic of chestnut ecosystems. An holistic approach including all the factors involved in chestnut trees ecology is proposed in planning the management of such ecosystems, and in undertaking best conservation and improvement measures.

Esca is a grapevine wood disease that seriously affects grapevine yield and longevity, comprising a number of distinct diseases in which the main fungal agents (primarily vascular pathogens) invade the vines, not only through field wounds but also as a result of nursery practices. When vines become infected in the nursery, the developing diseases may vary from Petri decline to full-blown esca, with or without white decay. No chemical control is available and sanitary practices in the nursery are suggested as the best way to eliminate or at least reduce pre-planting infections by the tracheomycotic fungi. In absence of chemical prevention, preventive and curative actions in the field can lower infections or hamper symptom appearance in esca-infected vines.

In the following chapter, the integrated management of root rot caused by the fungus *Rosellinia necatrix* on fruit tree crops is revised. This is a soil borne pathogen causing a disease known as “white root rot”. The pathogen, widespread in temperate and tropical climates, shows an increasing trend of attacks on several host species. Economic losses are serious in the nurseries and on orchard trees, and many field crops and weeds can also be severely damaged. The pathogen, mainly disseminated by propagating material, can survive in soil for many years. Control strategies, including cultural practices, soil disinfestations, chemical treatments, soil solarization and biological control are expensive and not always resolutive. White root rot control largely depends on pathogen exclusion through the use of *R. necatrix*-free propagating material and planting in healthy soils. A fundamental role is played by rules promoting trade of healthy propagating materials, and by the availability of new molecular detection tools.

The second Section, on annual crops, begins with a review of simulation models for potato late blight management. Potato late blight is widely studied and particular attention was given to the mathematical description of its development. Several simulation models are avilable and this chapter focuses primarily on versions developed at Cornell University and other research centres. The most recent version of the model was validated in the highland tropics and several other countries and cropping systems. Late blight simulators, used to evaluate disease management scenarios, were also used for other purposes, including sensitivity analysis of resistance components, comparative epidemiology, development of forecasting models and education. The potential of disease simulation will continue to improve, thanks to supporting technologies, both in computing power and weather data acquisition.

A review about the potentials of the decision support systems approach then follows, with an example of integrated forecasting system for management of *Phytophthora infestans* on potato. The PLANT-Plus® system initially developed in the Netherlands by Dacom, allowed management of *P. infestans* on-farm since 1994. The system is based on the life cycle of *P. infestans*, combining infection events with the unprotected part of the crop, and was extended with models for *Alternaria solani* and several other fungi or insect pests, in different crops. Another modules include the irrigation management system based on meteo data and soil moisture sensors, and models for potato tuber infection and fertilizers management. The platform enables data communication between farmer, consultants, processors and other users, allowing the most appropriate interface to be chosen. Different output types include SMS text messaging, fax and e-mail warnings. An integrated weather forecast provides a predictive risk assessment for the coming days. The disease models require the availability of automatic, on-farm weather data and were developed in cooperation with experts from different areas and countries. The model will recommend when to apply a new spray and what type of chemical to use, i.e. contact, translaminar or systemic. The benefits were demonstrated in field trials and evaluations all over the world, and provide safe spraying programmes with lowest possible use of chemicals.

A subsequent chapter deals with the integrated management of bacterial fruit blotch (BFB) of cucurbits, the most economically important bacterial disease of cucurbits worldwide. The causal agent is *Acidovorax avenae* subsp. *citrulli*. This chapter explores the current understanding of the biology and epidemiology of BFB and the integrated management strategies currently available. BFB is a seed transmitted disease, affecting all stages of cucurbit crops and causing destructive fruit rots. Like many phytobacterial diseases, the chemical options for management are limited and primarily include copper-based compounds. The unavailability of resistant cucurbits cultivars makes management difficult. An integrated approach to exclude primary inoculum through production of clean seeds is suggested, through isolation of seed fields, inspection and certification, seed health testing, seedling inspection and copper-based disease control. Despite the efforts to exclude the pathogen from cucurbit production, BFB outbreaks occur sporadically, worldwide. For a more effective integrated management, a better understanding of the disease epidemiology and pathogenesis is needed in fruit and seed production. Additionally, understanding the role of blossoms in seed infection revealed potential avenues for integrated disease management.

In the following chapter, a review of the progress in the integrated management of Sclerotinia rot of carrot is given. Bacterial diseases play an important role in the world agriculture by reducing yields and marketability of crops or by limiting their production in areas with environmental conditions conducive for disease development. Plant pathogenic bacteria show several obstacles for efficient plant protection practices. In spite of technological advances, there is no bactericide that can be efficiently used to control plant bacterial diseases. Due to lack of chemicals, plant pathologists search for alternatives i.e. the integration with preventive measures to develop sustainable control strategies. Management of tomato bacterial spot currently relies on use of pathogen-free seed and transplants, elimination of volunteer tomato plants, resistant cultivars and application of a copper-based bactericides. These practices are ineffective in hot and humid weathers that favor the pathogen spread and the disease development. New technologies, i.e. systemic acquired resistance inducers and biocontrol agents, integrated with conventional practices, represent new options in plant protection and increased disease management efficiency.

A review follows about the integrated management of Verticillium wilt of tomato. The disease is caused by *Verticillium dahliae* and *V. albo-atrum*, and its incidence and epidemiology are revised. Verticillium wilts are generally controlled by a combination of measures aiming at reducing severity and delaying the disease progress, including resistant cultivars or rootstocks, management of soil inoculum, reduction of propagules spread and manipulation of epidemiological factors. Further methods, including crop rotation, solarization, sanitation, tillage and weed control, fertilization, irrigation, chemical treatments and use of microbial antagonists, are also revised.

Sclerotinia rot, caused by the fungus *Sclerotinia sclerotiorum*, is an important disease of carrot in the field and during storage. Chapter 13 describes control methods, emphasizing emerging strategies supported by new information on its etiology and epidemiology. Prospects and recommendations are given to integrate current and emerging control methods for sustainable management. The primary strategy to manage Sclerotinia rot is the integration of methods reducing within-field sources of inoculum, suppressing the development of the fungus, and reducing the infection rate in the field and/or storage. The integrated strategy recommended in this review aims at achieving disease suppression through sanitation of soil and equipment, monitoring the crop development and microclimate, modifying the microclimate through canopy manipulation, predicting the disease and timing the application of control practices, as required. Breeding carrot cultivars for an upright and compact top growth may offer important contributions to the sustainable management of Sclerotinia rot.

Chapter 14 describes the integrated management of key diseases of cotton and rice. Issues related to disease identification and based on symptoms and presence of pathogens are discussed, as they are very important for a successful management. The main integrated management concepts are discussed, together with technologies combining a variety of control measures, including the conservation of existing natural enemies, crop rotation, intercropping and cultivation of pest-resistant varieties. Cotton diseases considered include seedling diseases, bacterial blight, Alternaria leaf spot, grey mildew and leaf spots caused by *Myrothecium*, *Cercospora*, *Helminthosporium*, *Macrophomina*, stem canker, late season Phoma blight, rust (*Phakopsora gossypii*), leaf crumple, Cotton Leaf Curl Virus, Tobacco Streak Virus, root rot, Verticillium and Fusarium wilts, new wilt or parawilt, boll rots and lint diseases. Rice diseases include rice blast, brown spot, bacterial leaf blight and leaf streak, sheath blight, sheath rot, Fusarium wilt or “Bakanae”, stem rot, Tungro Virus, false smut and post-harvest diseases.

A further review describes biological and integrated means to control rust diseases. In Chapter 15 the strategies avilable in rust control, with a special emphasis on biological control, are discussed in the light of evidence showing that disease control is most effective when an integrated approach is followed. A survey of the fungal antagonists (hyperparasites) most effective against rust pathogens is given. Their mode of action is described, and the main problems concerning biological control are discussed. The value and limitations of other control measures (eradication, use of hazard areas, quarantine, cultural practices, chemical treatments, and plant breeding for disease resistance) are also outlined. A consideration of all control measures suggests that crop protection requires an holistic approach, integrating a broad range of control techniques.

In the third and final section, two innovating research fields are revised: *i)* the use of DNA fingerprinting methods for microbial pathogens diagnostics, with potentials in taxonomy and plant disease and *ii)* the management of pests and diseases through the exploitation of endophytic fungi and their metabolites.

Advanced DNA-based techniques improved the identification and characterization of microbial pathogens, resulting in an accurate testing for pathogen identification, sub-species-level DNA fingerprinting, pathogen-load testing and disease spread monitoring. These applications are instrumental to the study of plant disease epidemiology, so that adequate control measures can be accordingly implemented. In Chapter 16, a survey of the most popular DNA profiling techniques is given, together with some new molecular methods. Combinations of different analytical techniques are also proposed as a useful approach for low throughput bioassays. Advantages and disadvantages of each single test are considered and key issues (i.e. sampling, validation, large-scale testing) are discussed. An outline of emerging high-throughput molecular technologies, improving diagnostic approaches and disease management, is also provided.

In the final chapter a new field of investigation with exciting perspectives in IPM/IDM is revised. Endophytes are non-pathogenic microorganisms inhabiting the interior of healthy plants, with potentials for crop protection. Many cultivated and wild type plants investigated showed presence of endophytic fungal metabolites including guanidine and pyrrolizidine alkaloids, indole derivatives, sesquiterpenes or isocoumarin derivatives. These metabolites show beneficial effects on crop plants and many of them have pesticidal and antimicrobial activity against plant as well as human pests and pathogens. Full potentials and efforts needed for their full exploitation are discussed.

In conclusion, our attempts to provide new options in management solutions available worldwide, in a broad range of agricultural systems, yielded a comprehensive compilation. We acknowledge the Author’s contributions for their outstanding work. Thanks to their experience, efforts and determination in seeking and applying advanced solutions in their research and field work, we hope we were able to provide a further tool, useful in the comprehension and sustainable management of plant pests and diseases. Our hope is that this volume, even if not exaustive, will result helpful for any interested reader, inspiring and supporting the research efforts today necessary in the field and laboratory work as well.

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