# Preface

As the science of rice pathology continues to advance, it is desirable not to lose our professional memories of where the science comes from and where it is heading—and how its progress can be applied to overcome some major rice production constraints that could benefit millions of resource-poor rice farmers and consumers.

Rice is the staple food to most of the people in Asia, which comprises 4.4 billion inhabitants accounting for 60% of world population. Since the introduction of modern high-yielding varieties (HYVs), a wide array of changes in the occurrence of rice diseases has emerged. Some of the changes are the result of the deployment of new rice varieties and others are due to changes in the cultivation method. Rice diseases are dynamic. Their occurrence and development are influenced by host genotypes, planting methods, and the microenvironment unintentionally altered due to modification of the plant's architecture and crop intensity with excessive nutrient inputs.

The rice diseases that initially afflicted HYVs are not new ones. From scattered information in the literature, most of these diseases were reported and considered "minor" prior to HYV introduction. The change in disease status seems primarily due to replacement plantings of HYVs that lacked diversity in resistance, continuous cropping facilitated by short duration and photo-insensitivity, and the monocrop culture of large areas planted to single varieties, or even later varieties with a narrow genetic background and more intensified cultivation patterns. The change in the balance of host-pathogen relationships has reinforced the threatening nature of these rice diseases. This is discussed further in Part I, Section 1 on the shifty enemies of rice production in Asia.

The occurrence of some rice diseases can be attributed to the performance of the production system. The purpose of documentation is to make sure that we do not lose track of the occurrence and development of some rice diseases, why they occur, and how they develop. It is a useful record and reference for scientists of future generations. As mentioned in this online resource, we recognize that the status of four groups of rice diseases has changed dramatically since the introduction of the first generation of HYVs. Whether or not this is the right grouping, the basis for the current grouping is discussed.

At first, we considered revising Ou (1972, 1985), a seminal work on rice diseases. After a literature review and discovering all the available new research and information, we realized that it would be an almost impossible task to revise it. So, we decided to produce a new resource, which, initially at least, is not being printed but made available online only. By doing this, we have been able to retain key information from Ou (1985) while reorganizing new information and research. The purpose of this effort is to present relevant information of research progress that has appeared in the literature since Ou (1985). This resource, in three parts, is introduced by Robert S. Zeigler, director general emeritus, and Hei Leung, plant pathologist, International Rice Research Institute (IRRI). They discuss the future impact of rice diseases tied to production systems becoming more diverse, changes occurring in the way rice will be grown, the adoption of hybrid rice, climate change, and the rise of new science and technologies for disease management.

Part I covers the importance of rice diseases and their impact on rice crop production in Asia, Africa, and the Americas. We demonstrate how the rise of some rice diseases is influenced by crop intensity, increases in host plant density, and the importance of host plant resistance when new rice varieties are introduced to large-scale planting. For some other diseases, their occurrence and development to a prominent status is more related to methods of cultivation and cultural practices.

Part II focuses on the biology of rice diseases caused by various pathogen groups. Also covered in Section 5 are recent advances in research. These include six chapters on:

- Biology of the rice blast pathogen,
- Molecular genetics of bacterial blight and bacterial leaf streak and the impact on future control strategies,
- Molecular genetics of major virus resistance in rice,
- Molecular biology of disease resistance in rice,
- Epidemiology of rice diseases and knowledge on the pattern of how different diseases develop in a rice crop population, and
- Abiotic stresses in rice.

The chapters on the biology of rice diseases provide information on most aspects of individual diseases in a condensed format. The intent is not to conduct a literature review of individual diseases but to use a textbook style to point out how some of the findings may be related to important plant pathology principles. Hopefully, readers will get an idea where the science of rice disease research has come from and how to apply some of the new research results to solve a disease problem, first by proper diagnosis, then either by varietal development and/or disease management. This resource also demonstrates how research on rice diseases in recent years has contributed to general plant pathology.
Of course, the authors also had a few "new" ideas in mind. Since the introduction of new HYVs, the changing scenario for rice diseases over the years has been influenced by altering the methods or techniques of rice cultivation and the deployment of new rice varieties lacking the required appropriate host plant resistance. For those diseases where this information is available in the literature, this has been identified and reflected.

A textbook format is used because this resource is not just a literature review, although there are around 3,500 references cited throughout. A lot of information has been distilled into—or shown to be related to—plant pathology principles or new knowledge. So, hopefully, graduate students—the new generation of rice researchers—will understand where the science in rice disease research is coming from and what progress has been made. We identify the starting point in rice disease research over the past three to four decades or so and what have been the driving forces and approaches?

It should be evident that key ideas have often been formed tied to working experiences at the International Rice Research Institute (IRRI) and its sister institutions. For instance, regarding bakanae seedling disease, because of IRRI's involvement in seed health testing, the authors have tried to relate the information to some of the questions about seed health and the seedborne-nature of the pathogen. The bakanae fungus (Part II, Section 1, Chapter 1) is an important plant quarantine pathogen carried and transmitted by rice seed. Unfortunately, Fusarium moniliforme is also a fungus bearing the same name causing diseases of many other crops in countries on different continents. Are they related? Might they really be coming from rice seed originating in Asia as claimed in some of the literature? If they are, could F. fujikuroi (the new taxon related to rice) be differentiated among rice and other crops, such as maize, sorghum, etc., or across continents such as Asia and Africa? The literature review is organized around answering these questions to help unveil such relationships. With this analysis, this resource should be useful, not only in the science of rice diseases, but also in general plant pathology.

One of the central points in this resource is how the research evolved around "host specificity." It was done this way because IRRI scientists have been directly involved over

the past decades and are still involved in such research. When this research started in the 1960s and 1970s, the question was—and still is—about host specificity, and how the pathogen prepares to invade or infect the host plant and how the host plant is prepared to defend the invasion or infection. The aim is to link the research starting from race-virulence to avirulence with effectors and receptors in recognition and specificity and with downstream signalling to understand how resistance operates at the cellular and molecular levels.

Is this the end? Not likely. Hopefully and expectedly, this will lead to the development of novel methods of genetic manipulation and, eventually, to better disease control and management practices. The authors provide a pathway on how the research has evolved. This should allow readers to trace the origin of the science of the diseases so that they can move forward by shaping or hypothesising the future research based on current up-to-date knowledge—any way they like. The latest on rice blast (Part I, Section 1, Chapter 2, item 12) demonstrates this idea. In addition, rice blast is a good example to show how and why the name of the fungus has been changed so frequently. What is the basis for these changes? It is more important regarding this particular fungal pathogen to show how a pathogen may evolve from being hemibiotrophic to biotrophic. Pathologists group plant pathogens into three categories: biotrophic, hemibiotrophic, and necrotrophic. So, readers may find some details in the biology of the rice blast pathogen. This is just an example of how this resource should be useful.

Part III covers disease management. A plant disease may be controlled using various options. Any chosen measure, however, must be based on a good understanding of the disease's biology and epidemiology. Plant pathology is an applied science. It aims to solve disease problems in crop production. The technology of disease management has to be science-based. After the Green Revolution, controlling rice diseases involved an organized effort from developing resistant varieties to deploying them in farmers' fields. These varieties may carry resistance genes against some of the major diseases. In disease management, effectively deploying resistance genes, which have been incorporated into the rice plant to create resistant varieties, is as important as developing the resistant varieties themselves. Besides managing the resistance genes to control rice diseases, the other urgent issue is dealing with several other diseases collectively within a rice-cropping season. Most farmers in the rice-growing countries of South and Southeast Asia are either tenant farmers or small landholders who depend on rice farming for their subsistence. Their rice crop management is not aimed at disease control alone but for overall good crop growth, thus a good crop harvest. It is desirable and feasible to identify their crop management practices so that a means can be provided to reduce disease occurrence and incidence.

Since the Green Revolution, most of the rice varieties planted by farmers are resistant to three or four of the major diseases. Whether such built-in resistance is durable is a scientific issue that needs to be studied. However, scientists are aware that the host and its pathogen, especially biotrophic or hemibiotrophic pathogens, coevolve, each responding to the other. In this context, researchers must not only aim at host-pathogen interactions, but also include farmers' cultural practices that could potentially minimize the arms race between the host and the pathogen eventually reducing or preventing disease occurrence and incidence. Since the last century, leading plant pathologists have called attention to "make sure that our profession is useful." They have pointed out that "understanding the economics of plant disease management is one of the greatest deficiencies" of our science (Horsfall and Cowling 1977).

The management options included in Part III, namely resistance deployment and management of microbial antagonists carried by rice seeds or dwelling in rice ecosystems, have been integrated as components in rice crop management. The choice of practice is not arbitrary but based on research, especially from the epidemiological process of

disease development. In addition, the authors use a participatory research process to engage rice farmers to scale up the technology of disease management. A rice crop may be attacked by many diseases at a given time. A few questions may then be asked. Must the rice disease management strategy be designed to control all, or just selected ones, especially those with high epidemic potential? Are there other options to make the crop healthier, such as taking a "public health" option approach (an idea originated by wheat pathologist E.C. Stakman in the 1940s) to minimize disease control measures? Evidently, after assessing all possible options, making the rice production system healthier is the best option.

In brief, for general disease management, we hope to promote a rice production system that begins with soil, seed, and crop health along with deployment of rice varieties with diverse resistance genes. Thus in disease management, it is not our intention to give a "shopping list" on how individual diseases could be managed. We provide a few general measures that work effectively for more diseases. For instance, seed health management for disease control is not a new approach. However, few if any in the literature—past or present—have tried to practice it. However, the authors here have tried to point out the relationships between seed pathology and seed health and what are the plant pathological principles that seed health management is based on. This is not new, but few have done it in the way we have.

The other examples are applying rice-associated microbial antagonists on biocontrol of rice fungal diseases and genetic diversity for rice disease management. In the former, biological control agents, the antagonistic bacteria are applied to disrupt the disease development process to reach disease control. In the latter, we point out the principle involved in genetic diversity and its feasibility for what types of diseases and how it may be done. No matter which measures are used, the application has to be based on the epidemic process of disease development to identify the intervention point.

S.H. Ou, IRRI's first principal plant pathologist, wrote the first most comprehensive book on rice diseases (Ou 1972, revised in 1985). He synthesized research information available at that time. We, as his followers, tried to continue the effort. Instead of revising his book, we decided to take a different approach to integrate part of the information with other new research and information to distill new knowledge about plant pathology. It is too early to say if we have succeeded in doing so. We have tried to put the most relevant information together in this one online resource for all to access so that progress can continue while not losing our professional memory. The distilled knowledge in the plant pathology of rice disease research is the task of many pioneers conducting research over the past several decades. In the end, it precipitates into what we know about the various aspects of rice diseases and the science. However, research may have a beginning but there is no end. Today's knowledge is built on top of yesterday's research. This will be obvious as more updated information is placed on this unique and evolving online resource. As mentioned earlier, we originally began with the hope to make this a traditional printed textbook. Such a textbook would have had a uniform format and style. As the authors proceeded in writing, this seemed to be a desire rather than a reality. The science of rice disease research has become a very multi-faceted model in modern biology. It is not likely that any individual scientist, such as Dr. Ou in his time, could achieve in covering all aspects of the research. So, we decided to involve different authors with different expertise to write the various sections and chapters. Although we have tried to some degree to maintain a "similar" style, differences are obvious. As scientists, we all have our own style in doing research and reporting the results. Much of this difference has also been expressed in the different writing and publications we each have authored. In the end, uniformity has become a target but diversity is the result. For this reason, the content of individual sections or chapters in this online resource is obviously the responsibility of the authors.

Special Note: In order to have a soft launch of this online resource in time for two major rice disease conferences in Manila in October 2016, many sections and chapters are still not available online. However, we strived to have online the latest information available on the two important diseases covered in the conferences, rice blast (Part I, Section 1, Chapter 2, item 12) and bacterial blight (Part I, Section 2, Chapter 1, item 1). Other sections and chapters listed in this resource's Table of Contents will have a hotlink, if available; if not, it indicates what will be forthcoming in the near future.

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September 2016

## References

Horsfall, J. G. Cowling, E. B. 1977. Prologue: how disease is managed. In Plant Disease—an advanced treatise, J. G. Horsfall and E. B. Cowling, eds, Academic Press, New York, pp1-9.

Ou, S. H. 1972. Rice diseases. 1st ed. Commonwealth Mycological Institute, Kew, U.K.

Ou, S. H.1985. Rice diseases. 2nd ed., Commonwealth Mycological Institute, Kew, U.K.