Fifth Edition

PLANT PATHOLOGY

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GEORGE N. AGRIOS
Department of Plant Pathology
University of Florida

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This, the 5th and probably the last edition of *Plant Pathology* by me, is dedicated:

To the memory of my parents, Nikolas and Olga, who, in spite of their limited education, sacrificed everything to give me the most and best education possible.

To the memory of Dr. Walter F. Buchholtz, my major professor at Iowa State University, who challenged me before I had even taught my first lecture to "write my own textbook on Plant Pathology".

To my sisters, Dimitra and Evangelia, who have been there for me forever and who also sacrificed some of their interests for my benefit.

To my wife, Annette, whose love and support have been the most precious things to me throughout our life together, and who helped me in many facets of preparation of this and of previous editions of *Plant Pathology*.

To my daughters-in-law, Betsy and Vivynne, who, by joining our family, added beauty, love, enjoyment, and four wonderful grandchildren.

Finally, to Mark and Maximos, our youngest grandchildren, who, someday, when they read their names in the book, may be reassured of "Granpa's" love for them, and may feel proud of their grandfather.

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Preface

Since the appearance of the 1st edition of *Plant Pathology* in June 1969, tremendous advances have been made both in the science of plant pathology and in the publishing business. New information published in the monthly plant pathological and related biological journals, as well as in specialized books and annual reviews, was digested and pertinent portions of it were included in each new edition of the book. The worldwide use of the book, in English or in its several translations, also created a need to describe additional diseases affecting crops important to different parts of the world. There has been, therefore, a continuous need to add at least some additional text and more illustrations to the book with as little increase in the size of the book as possible. Fortunately, through the use of computers, tremendous advances have been made in the publishing business, including paper quality and labor costs and, particularly, in the reproducibility and affordability of color photographs and diagrams. Plant diseases and plant pathology come alive when illustrated in full color and it has been the author's dream to have all the figures in color. Add to these advances the interest of the author and of the publishers to spare no effort or expense in the production of this book and you have what we believe is the best book possible for the effective teaching of plant pathology at today's college level worldwide.

To begin with, "Plant Pathology, 5th edition" provides each instructor with all the significant new developments in each area and gives the instructor choices in the type and amount of general concepts material (Chapters 1–9) and of specific diseases (Chapters 10–16) he/she will cover. Each chapter begins with a fairly detailed, well-organized table of contents that can be used by students and instructors as an outline for the chapter. The instructor can also use it to cover parts of it in detail in class while some of the topics are covered briefly and others are assigned to the students as further reading. Each student, however, has all the latest material, well organized and beautifully illustrated, available in a way that is self-explanatory and, with the complete glossary provided, can be understood with minimal effort.

Instructors will have an even greater choice in the kinds of specific diseases one would use in a specific area of the country or of the world where one teaches. While one may want to include the teaching of potato late blight, apple scab, wheat rust, bacterial soft rot, root knot, and some other diseases of general interest, one often also wants to cover diseases of particular interest in the region, both because of their regional importance and because of their availability locally for further study in the classroom and the laboratory. This edition makes this possible by covering and illustrating in full color a wide variety of diseases, some of which are important to the grain plains of the Midwest and the northwestern United States, others to the fruit- and vegetable-producing Pacific and northeastern states, others to the

cotton-, peanut-, tobacco-, rice-, and citrus-vegetable producing southern states, and so on. A special effort has also been made to describe and to fully illustrate in full color several diseases of tropical crops important in different parts of the world, such as rice in the Far East, beans in Central and South America, cassava, cacao, and sorghum in Africa, and tropical fruits such as citrus, papaya, coconut, and coffee in the Americas, and so on. Instructors can pick and choose to study, in the classroom and, if possible, in the laboratory, whatever diseases of whichever crops they deem most significant for the particular area and for the ever-shrinking world we all live in.

The overall arrangement of this edition is similar to that of previous editions. However, all aspects of the book have been thoroughly updated and illustrated. Newly discovered diseases and pathogens are described, and changes in pathogen taxonomy and nomenclature are incorporated in the text. Changes or refinements in plant disease epidemiology and new approaches and new materials used for plant disease control are discussed. The chapters on diseases caused by prokaryotes (bacteria and mollicutes), especially the one on diseases caused by plant viruses and viroids, have been revamped due to the large amount of new information published in recent years about such pathogens and diseases. And in all cases, partial tables of contents have been added to each chapter and to its main subdivisions for better clarity and understanding of the arrangement and inclusion of the topics in the appropriate subdivisions. A new feature that has been added to the book is the presentation of a number of topics of special interest in separate boxes. In these, the various topics are approached from a different angle and highlight the importance of the topic whether it has historical, political, or scientific significance. Special attention has also been given to highlighting the historical developments in plant pathology and the scientists or others who contributed significantly to these developments.

As in other recent editions, much of the progress in plant pathology has been in the areas of molecular genetics and its use in developing defenses in plants, against pathogens. Discoveries in basic molecular genetics, particularly discoveries in how plants defend themselves against pathogens and in the development of mechanisms to produce disease resistant plants, receive extensive coverage. It is recognized that some of the included material in Chapters 4 (Genetics of Disease), 5 (How Pathogens Attack Plants), and 6 (How Plants Defend Themselves against Pathogens) may be both too much for students taking plant pathology for the first time and somewhat difficult to follow and comprehend. However, the importance of that material to the future development of plant pathology as a science and its potential future impact on control of plant diseases is so great that its inclusion is considered justified if only to expose and initiate the students to these developments.

There are numerous colleagues to whom I am indebted for suggestions and for providing me with numerous slides or electronic images of plant disease symptoms or plant pathology concepts that are used in the book. Their names are listed in the legend(s) of the figures they gave me and in the list of "Photo Credits." I would particularly like to express my sincere appreciation and thanks to Dr. Ieuan R. Evans of the Agronomy Unit of the Alberta Agriculture, Edmonton, Alberta, Canada, who, as editor of the slide collection of the Western Committee on Plant Disease Control, provided me with hundreds of excellent slides and permission to use them in the book. I also thank Dr. Wen Yuan Song for reviewing the chapter on "How Plants Defend Themselves against Pathogens." Finally, I again thank publicly my wife Annette for the many hours she spent helping me organize, copy, scan, and reorganize the many slides, prints, and diagrams used in this book. Not only did she do it better, she also did it faster than I could have done it.

George N. Agrios
July 2004

Photo Credits

The need for high-quality photographs to include in this book necessitated the request of appropriate photographs from colleagues around the world. All of them responded positively and I am very thankful to all of them. I am particularly indebted to the following individuals and organizations who, although I was asking from them one or a few photographs, sent me those plus all the related or other pertinent photographs that I might want to use in the new edition of the book. Moreover, several of them offered to give me any other photographs they had and which I might want to use.

I am particularly indebted to Dr. Ieuan R. Evans of the Agronomy Unit, Agriculture, Food, and Rural Development of Alberta, Canada, for providing me with several hundreds of slides put together by the Western Committee on Plant Diseases (WCPD) for general use for educational purposes. Those contributing slides through the WCPD include P. K. Basu, Agriculture Canada, Ottawa, Ontario; J. G. N. Davidson, Agric. Canada, Beaverlodge, Alberta; P. Ellis, Agric. Canada, Vancouver, British Columbia; I. R. Evans, Agric. Canada, Edmonton, Alberta; G. Flores, Agric. Canada, Ottawa, Ontario; E. J. Hawn, Agric. Canada, Lethbridge, Alberta; R. J. Howard, Alberta Agriculture, Brooks, Alberta; H. C. Huang, Agriculture Canada, Lethbridge, Alberta; J. E. Hunter, NYAES, Geneva, New York; G. A. Nelson, Agriculture Canada, Lethbridge, Alberta; R. G. Platford, Manitoba Department of Agriculture, Winnipeg, Manitoba; and C. Richard, Agriculture Canada, Sainte-Foy, Quebec.

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I am also thankful to several other organizations that gave me permission to use many of their photographs and offered to give me any others I might need. They include the Extension Service of the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), the American Phytopathological Society, and several United States Department of Agriculture (USDA) Laboratories. I am particularly thankful to the USDA Forest Service along with the University of Georgia who, through "Forestry Images" and "Bugwood Network," provided me with several images of forest tree diseases.

I am particularly indebted to the following colleagues, listed alphabetically, each of whom gave me numerous slides or electronic images and offered to give me as many more of their photographs as I needed: Dr. Eduardo Alves, Federal University of Lavras, Brazil; Dr. Mohammad Babadoost, University of Illinois; Dr.

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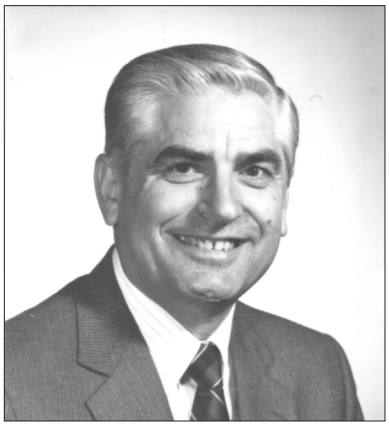

About the Author

Professor George N. Agrios was born in Galarinos, Halkidiki, Greece. He received his B.S. degree in horticulture from the Aristotelian University of Thessaloniki, Greece, in 1957, and his Ph.D. degree in plant pathology from Iowa State University in 1960. Following graduation he served 2 years as an officer in the Engineering Corps of the Greek army. In January 1963 he was hired as an assistant professor of plant pathology at the University of Massachusetts at Amherst. His assignment was 50% teaching and 50% research on viral diseases of fruits and vegetables. His teaching included courses in introductory plant pathology, general plant pathology, plant virology, and diseases of florist's crops. His research included studies on epidemiology, genetics, and physiology of viral diseases of apple, cucurbits, pepper, and corn, in which he directed the studies of 25 graduate students and published numerous journal publications. Dr. Agrios was promoted to associate professor in 1969 and to professor in 1976.

In 1969, he published the first edition of the textbook "Plant Pathology" through Academic Press. The book was adopted for plant pathology classes at almost all universities of the United States and Canada and of most other English-speaking countries. The first edition was later followed by the 2nd edition (1978), 3rd edition (1987), and 4th edition (1997). The book was translated into several major languages, including Spanish, Arabic, Chinese, Korean, and Indochinese, and became the standard plant pathology text throughout the world.

In the meantime, Dr. Agrios served on several departmental, college and university committees as well as committees of the northeastern division of the American Phytopathological Society (APS) and of the national APS. He was elected president of the northeastern division (1980) of APS. He was instrumental in founding the APS Press, of which he served as the first editor-in-chief (1984–1987). He was elected vice-president of APS in 1988, serving as vice-president , president-elect, and president (1990 and 1991). In 1988, professor Agrios accepted a position as chairman of the Plant Pathology Department of the University of Florida, overseeing approximately 50 Ph.D. plant pathologist faculty. Half of the faculty were located at the university campus in Gainesville, Florida, while the others worked at 1 of 13 agricultural research centers throughout the state of Florida where they studied all types of diseases of various crops. In 1999, the Florida Board of Regents approved the establishment of the new and unique Doctor of Plant Medicine Program and professor Agrios was appointed its first director. In 2002, Dr. Agrios relinquished his position as chairman of the Plant Pathology Department to concentrate on his duties as director of the Doctor of Plant Medicine Program. In June 2002, however, health reasons forced Dr. Agrios to retire from the University of Florida.