FUNGAL PLANT DISEASES IN EUROPE AND IN THE MEDITERRANEAN BASIN

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Contents

Summary

Mycological plant pathology, a branch of plant pathology (phytopathology) studies plant diseases caused by fungi and fungi-like organisms. Although humanity has been

concerned with plant diseases since pre-history, phytopathology has first developed into a scientific discipline only during the 19th and 20th centuries. The European and Euro-Mediterranean areas, and the other southern and eastern areas of the Mediterranean Basin which are dealt with in this chapter, are characterized by large climatic diversity and diverse plant populations, either cultivated or wild. Therefore a large number of fungi may cause numerous plant diseases, which can be widespread or limited in their distribution, and result in more or less severe impact on yield or quality of produce and possibly on the ecosystems. Diagnosis of disease, identification of the pathogen to the level of species or below (race or pathotype) and knowledge of pathogen biology and disease epidemiology are prerequisites for efficient disease management. Disease control options include exclusion of the host from an area (quarantine measures, certification schemes for seed and multiplication plant material), appropriate selection of cultural practices (crop rotation, fertilization, tillage, irrigation systems etc.), use of resistant host cultivars, and the recourse to chemical (fungicides), physical (e.g. soil solarization) and biological control agents. Several organizations, national and international, operate in the European and Mediterranean area in the fields of research, extension, legislation formation and enforcement. New challenges, related to rapid trade intensification and globalization, demographic and socio-economic variations, as well as climate change, are facing the plant protection organization at large. The existing human resources, structures and overall organization suggest that the Region may efficiently face these new challenges, although the support of society and some degree of re-organization will be required to face the rapid evolution of our world.

1. Introduction

1.1. Mycological Plant Pathology

Plant pathology, or phytopathology, is the science that studies the diseases of plants. It has the practical aim of protecting plants and their products from disorders caused by unfavorable environmental conditions, nutrient deficiencies, toxicities and parasitic organisms. Mycological plant pathology is the branch of plant pathology dealing with diseases caused by micro-organisms belonging to the kingdom of Fungi. Also diseases caused by ‘fungal like’ organisms, formerly considered fungi, like Oomycetes (Stramenopiles) and Plasmodiophoridae (Cercozoa) are still studied by mycologists. These will be included in this chapter under the cumulative epithet of ‘fungal pathogens’.

1.2. A Sketch of the History of Mycological Plant Pathology in the Area

In the Mediterranean Basin, dawn of civilization appeared over 10,000 years ago and agriculture was crucial in supporting growing human populations. Plant diseases caused by fungi were present and are known to have caused concern in these areas throughout history. Besides fossil records and representations in works of arts, the occurrence of plant diseases were recorded by Homer and in the Old Testament of the Bible. Ancient Greek philosophers like Democritus and Theophrastus dealt with diseases and death of plants and speculated about their causes. In the ancient Roman period, plant diseases are cited by Lucretius, Pliny the Elder, Columella and others. Religious ceremonies devoted to Rubigo, the deity related to rust of cereals were celebrated well into the Christian era.

Although Lucretius referred plant disorders to excess of sun or moisture, these phenomena were mostly considered manifestations of the wrath of God(s) for human sins. This attitude continued during the Middle Ages, with a few exceptions, among which the writings of the Arabian Ibn-al-Awam (10th Century, Seville, Spain), who described symptoms of plant diseases and gave consideration to their control, are included.

In the 17th Century, in France, empirical observations linking barberry to the rust of wheat leaded to the decree of Rouen, 1660, the first legislation on plant protection, ordering the destruction of barberry to prevent wheat rust. The development of the microscope resulted in the first observations of microorganisms, including fungi, in several countries of Europe. Outstanding contributors include Robert Hooke in England, Anton van Leeuwenhoek in the Netherland and Marcello Malpighi in Italy.

The pre-modern (or autogenetic) era followed. In France, Joseph Pitton de Tournefort (*Observations sur les maladies des plantes,*1705) attempted to describe the state of the art and distinguished diseases as induced either by internal or external causes. Henri-Louis Duhamel de Monceau described a fungal disease on the bulbs of saffron (1728). In Italy, Pier Antonio Micheli (*Nova plantarum genera*, 1729) gave a name to genera of microscopic fungi and observed their reproduction by "dust" (spores). Stephen Hales in *Vegetable Staticks* (1727), Jean Baptiste Aymen (Recherches sur le progrès et la cause de la nielle, 1760) found fungi on diseased plants. Nevertheless the *theory of the spontaneous generation* was still largely accepted: the relationship between fungal microorganisms and disease was not yet understood. The etiological concept appeared in the publication of Mathieu Tillet on bunt (*Dissertation sur la cause qui corrompt et noircit les grains de bled dans les épies; et sur les moyens pour prevenir ces accidents*, 1755) and was expressed in terms of host invasion and parasitism by Giovanni Targioni Tozzetti (*Alimurgia,* 1767) for the rust of wheat. Detailed treatises were written by plant physiologists, among them the German Johann Baptist Zallinger zum Thurn (*De morbis plantarum cognoscendis et curandis dissertatio ex phaenomensis deducta,* 1773) and Franz Joseph Unger (*Die Exantheme der Pflanzen und einige mit diesen verwandete Krankheiten der Gewachse, pathologisch und nosographisch dargestellt,* 1833). Although the microorganisms in diseased tissue were described as autonomous entities, the ailments of plants were attributed to unfavorable soil conditions, climate, or the inherent disposition of the plant to become diseased. At the same time botanists as Augustin-Pyramus de Candolle (*Regni vegetabilis systema naturale*, 1818-1821) continued developing the mycological taxonomic approach on which is based the transition to, and the beginning of, a new era. Isaac-Bénédict Prévost (*Mémoire sur la cause immédiate de la carie oú charbon des blés, et de plusieurs autres maladies des plantes, et sur les préservatifs de la carie*, 1807) considered fungi as casual agents of diseases but his work was largely neglected for decades.

In the modern (or pathogenetic) era the studies of the brothers Tulasne, Louis René (1815-1885) and Charles (1816-1884), unfolded the polymorphism in fungi and revived Prévost's work. The medical studies on human parasitism, and the studies of Louis Pasteur (1822-1895), Anton Justus Freiherr von Liebig (1803-73) and Charles Darwin (1809-1882) influenced also thinking and methodology related to mycological plant pathology. The *germ theory* finally replaced the theory of spontaneous generation.

At the same time, several plant diseases were impacting on the economies and societies of European nations. As a consequence of potato blight in Ireland, in a population of eight million inhabitants, over two million died or emigrated (1845-1849). The disease extended to other European countries, although with less dramatic effects because populations outside Ireland were less dependent on potato as a staple food. Powdery mildew in the 1840s and downy mildew of grape since 1878 had major impact in wine producing countries. These events stimulated research and induced governments to support studies on a permanent basis. The German Anton de Bary described the nature and the life history of the causal pathogen of the Irish famine (1861), and established (1865) the relation of the fungal aecidium on barberry to the rust on wheat. In 1858, Julius Gotthelf Kühn published Die *Krankheiten der Kulturgewachse, ihre Ursachen und ihre Verhiitung,* the first extended text-book on plant pathology based on the causal relationship between fungi and plant diseases. Modern mycology was born. Governments established, in Europe and in areas under European influence, research stations and chairs devoted to, or including, the study of mycology. Pierre Marie Alexis Millardet discovered the copper-based fungicide Bordeaux mixture (1882-1883), which saved the French and other wine industries. It also assured the control of several major diseases, becoming the universal fungicide and, flanked by lime-sulphur, maintained a place among the major fungicides of our time.

The subsequent period is marked by progress of mycology at an increasing pace. Taxonomic studies developed deeply and widely. The monumental *Sylloge fungorum omnium hucusque cognitorum* (25 volumes, 1882-1931) produced by Pier Andrea Saccardo and collaborators to classify and describe all the known species of fungi provides an example. New powerful tools derived from the re-discovery of the work on plant genetics of Gregor Mendel (1822-1884) at the beginning of 1900, and from the invention of the electron microscopy (1931-1933) by the German Ernst Ruska. In 1885, the US Department of Agriculture established a Section of Mycology: a new country outside Europe had started its significant participation to the advancement of the discipline. Elvin C. Stalkman (University of Minnesota) demonstrated the physiological (intra-specific) specialization of rust fungi, Harold Flor (North Dakota University, 1946) enunciated the *gene-to-gene theory*. With these outstanding contributions, and many others, plant resistance to pathogens opens new ways to disease control and to the understanding of the host pathogen relationship. Plant pathology research now involves most of the world and the countries of the European and Mediterranean area actively contribute to the general advancement of science.

The DNA model description by the American James D. Watson and the Briton Francis H. Compton Crick (1953) opens a new era for biological sciences and provides powerful tools for the advancement of science. Mycology largely applies them to study mechanisms of diseases and systematics. Mycological plant pathology has grown into a multidisciplinary science interwoven with botany, microbiology, crop science, soil science, ecology, genetics, biochemistry, molecular biology, physiology and other disciplines. It would be impossible to mention here its landmarks and even the most outstanding scholars in the contemporary era. Their contributions to the science underpin the contents of the following sections of this chapter.
Further reading: Whetzel (1918); Woodham-Smith (1962); Large (2008); Ainsworth (2009).

1.3. Damages Caused by Pathogenic Fungi

Like humans and animals, plants suffer from diseases. Diseased plants furnish a lower (in quantity or quality) production, creating concern for those people who obtain their income, directly or indirectly, from plant and plants products. But they create also concern for those people interested in plants for their beauty or their contribution to the landscape and for environmental protection. An average of over 14% of world losses is attributed to plant diseases altogether (Agrios, 2005), and more than 50% of plant diseases are caused by fungi, with billion euros of losses each year. Fungal plants pathogens normally do not cause diseases to humans, nevertheless they can be harmful to humans because the production of toxic metabolites (mycotoxins) that can accumulate in plant material and food; this aspect is not included in this chapter.

Fungi and fungal-like pathogens may be widespread or limited in distribution and have diverse impacts on human welfare. Threats to food security arising from yield reduction of staple crops may dramatically affect poor communities, particularly in developing countries. Economic consequences of diseases include increased costs because of additional diseases management practices to be applied and negative effect on trade, including loss of markets because of: (i) legal constraints on quarantine organisms, (ii) reduced or irregular supply of commodities. Moreover, plant pathogenic fungi cause post-harvest loss impacting on marketing and on food security by affecting availability of supply between crops.

Fungal pathogens may have direct or indirect negative influence on species providing ecosystem services (MEA, 2005) including consequences arising from the application of pesticides.

The European and Mediterranean area is characterized by a great diversity of cultivated and wild species, biodiversity generally increasing from the internal lands towards the Mediterranean coast and from northern to southern Europe. Different species of cereals are grown over a large proportion of cultivated land in most countries of the area. The very ancient 'triad' cereals-grape-olive is still very important around the Mediterranean and grapes extend farther north in Europe. Potato, grain legumes, oil crops, sugar beets, vegetables, fodder crops are widely grown. Fruit trees are widely represented. According to the different climatic conditions, citrus species, peach, almond, apricot, plum, pear, apple, hazelnut, kiwifruit, date palm etc. are cultivated. Temperate and boreal forests, and other wooden lands, (conifers, oaks, beech, birch, chestnut, walnut, etc.), maquis, garrigues and wetlands are largely present and they are rich of plant species. Several species of trees are also grown in gardens, parks and along urban alleys or rural roads, several of them being of great historical or landscape value (e.g. plane trees, elms, cypresses). All these plants species may be affected by fungal diseases to different extent (Appendix 1). Some diseases, such as potato late blight, have had a dramatic impact and still require careful management to prevent severe damage; others had changed the landscape of towns and countryside, like Dutch elm disease, which practically eliminated elm trees in many countries. Some, as wilt (*bayoud*) of palms, are an impending treat to the economy and environment of north African oases, and to ornamental palms (Figure 1) or, as ash dieback in Northern Europe, are emerging diseases threatening widespread plant trees.(http://www.eppo.org/QUARANTINE/Alert_List/fungi/Chalara_fraxinea.htm).

Further readings: Anonymous (1979), Smith et al. (1988), other references on Regional and Country Lists of Plant Diseases can be found in Waller et al. (2002), Bayer Crop Science Crop Compendium: http://compendium.bayercropscience.com/bayer/cropscience/cropcompendium/bcscropcomp.nsf/id/EN_7QLJZH_Overview. APS Press publishes a series of booklets about diseases and pests of specific crops: (http://www.apsnet.org/apsstore/shopapspress).

Figure 1. Necrosis of leaves of *Phoenix canariensis* affected by *Fusarium oxysporum* f.sp. *canariensis* (Image G. Vannacci)

2. Plant Pathogenic Fungi

2.1. General Aspects

About 80,000 species of fungi have been described (Kirk et al., 2001) and Hawksworth (1991) gave a conservative estimate of about 1,500,000 species of fungi existing in the world. Among them, about 10,000 are known to able to attack plants, compared to the about 50 species able to cause disease in humans (Agrios, 2005). Some species have a wide host range, while others specifically attack only one host plant species. Plant pathogens can have a wide geographical distribution encompassing many different countries, their distribution being limited by climatic factors only. Nevertheless, within the climatic area conducive to the development of a specific pathogen, one or more countries can be free of such an organism. A pathogenic fungus can therefore be classified as *quarantine pest* ("a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled") for these countries and rules are raised to avoid the introduction of the pathogen (OEPP/EPPO, 2010). Fungi that do not fit the quarantine pest definition, are qualified as *quality pathogens*, they are present in the area of interest and affect the quality, and/or quantity, of crop production. Fungal pathogens that require a living host to complete their life cycle are defined obligate parasites (or biotrophs) (Figure 2), whereas those (saprotrophes) that spend a portion of their life on dead plant material or other organic matter (for example the artificial substrata usually employed in mycological laboratory) are called nonobligate or facultative parasites (or necrotrophs) (Figure 3).

Figure 2. Symptoms of powdery mildew, caused by the biotrophic fungus *Blumeria graminis*, on barley plants (Image G. Vannacci)

The latter, frequently kill host tissues by means of toxins or enzymes and feed and reproduce on the killed tissues. Necrotrophic fungal pathogens derive their nourishment by absorbing soluble nutrients through the wall and plasmalemma and they break down complex polymers by releasing extracellular enzymes (as usually do saprotrophic fungi), biotrophic fungal pathogens usually derive nutrients from living plant cell through specialized cells called haustoria. Pathogenic fungi can colonize the host plant systemically, growing within the vascular system, such as *Verticillium dahliae* on many crops (Figure 4), while others colonize a limited amount of plant tissues, feed on them and then leave the plants by means of reproductive organs (Figure 5) in order to infect the same or another plant.

Symptoms of a disease could be the consequence of the necrosis of tissues (leaf spots, blight, canker, dieback, root- and stem- rots, soft- and dry- rots of fleshy organs, damping off, anthracnose, scab), abnormal growth (hyperplasia, hypoplasia) of tissues (wart, galls, clubroot, witches' brooms, leaf curls, dwarfing), modification of the general appearance of the plant (wilt, decline) or can be the consequence of plant tissues alteration and the concurrent production of reproductive or vegetative structures of the pathogen (rust, smut, mildew) (Fig 6)..

Figure 3. Stem canker caused by the necrotrophic fungus *Cryphonectria parasitica* girdling a young trunk of *Castanea sativa*. Note the production of adventitious shoots below the canker (Image G. Vannacci)

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Biographical Sketches

Angelo Porta Puglia graduated in Agricultural science in 1967 from the University of Turin, Italy, where he benefited of a post-graduate grant from the Italian Ministry of Education (1968-1969) for teaching and scientific training in plant pathology. In 1979 he spent 4 months at DGISP (presently DSHC), Copenhagen, Denmark to specialize in Seed Pathology. Researcher at the Istituto Nazionale Piante da Legno, Turin, Italy (1969-1971 and 1974-1976), plant-pathologist with FAO in Algeria (1971-73), researcher (1977-1987) and director (1987-2003) of the section Epidemiology and Resistance at the Istituto Sperimentale per la Patologia Vegetale (presently CRA-PAV), Rome, Italy, mycologist and adviser in plant pathology, Ministry for Rural Affairs and the Environment, Malta (2004-2006). Deputy editor (1991-1996) and deputy co-editor (1997-2010) of the scientific journal *Petria* and presently member of the editorial board of *Protezione delle Colture*. He has been FAO consultant in several African countries. Since 2006 he is member of the Plant Health Panel of the European Food Safety Authority (EFSA), Parma, Italy. Member of several international and national scientific societies, he has been vice-president (1994-98) of the European Association for Grain Legume Research, Paris, France. He was co-awarded the prize *Grifo d'oro*, 1994 by the National Institute for Risk Prevention in Technological Activities, Rome, Italy, for research on chickpea disease-resistant cultivars. He has published more than 250 contributions on plant pathology, including one book, monographs and proceedings as editor or co-editor; book chapters, original research papers, reviews and invited papers as author.

Giovanni Vannacci graduated in Agricultural science in 1973 from the University of Pisa, Italy, where he benefited of a post-graduate grant from the National Research Council for a scientific training at the Institute of Plant Pathology. In 1979 he worked at the Società ItaloAmericana Prodotti Antiparassitari (SIAPA). University researcher (1981-1992), associate professor (1992-2001), full professor (2001 to date) of Plant Pathology at the Faculty of Agriculture of the University of Pisa. In 1984 he spent six months at the New York Agricultural Experimental Station at Geneva (NY, USA) working on biocontrol of fungal plant pathogens. He teaches Mycology and Biopesticides at the Agroindustrial biotechnology university course. He has been Director of the Dept of Tree science, Entomology and Plant Pathology *G. Scaramuzzi* of the same University (2003-2009), Managing Editor of Journal of Plant Pathology (1997 - 2002), President of the organizing committee of the 6th European Conference on Fungal Genetics (2002) and he is member of the advisory group on Plant Diseases of the *Accademia dei Georgofili* (since 2009) and of the Steering Committee of the Italian Phytopathological Society (since 2010). He has been member of the International Subcommission on *Trichoderma* and *Hypocrea* of the International Unions of Microbiological Societies and of the Plant Protection Commission of the International Society for Horticultural Science. He has been peer reviewer of research project for National and International funding Agencies and reviewer for national and international scientific journal. His main expertise is biological control of plant pathogens by antagonist fungi, but in more than 35 years of activity he has been involved in researches on biology and molecular biology, genetic variability, systematics of fungi as plant pathogens, biocontrol agents and bioremediation tools. He is author of more than 150 papers on scientific journals.