Chapter 2

Significance of Plant Pathology

EPIDEMIOLOGY OF PLANT DISEASE

Epidemiological observations, that is, observations concerning increase of disease within plant populations and how such increases relate to environmental factors, were recorded with many plant diseases as the latter began to be reported. Little effort was made, however, to correlate and utilize such information in controlling plant diseases. From studies of the apple scab disease, Mills in 1944 developed a table listing the duration of rain required at each temperature for apple buds, leaves and fruit to become infected by the ever-present apple scab fungus. He, and others, then could use this information to predict whether infection would take place and whether, therefore, control measures (fungicides) should be applied.

It was in 1963, however, that through the book *Plant Diseases: Epidemics and Control* Vanderplank established epidemiology as an important and interesting field of plant pathology. In his book, Vanderplank discussed the principles and variables in plant disease epidemics, stated the difference in the development and control of monocyclic and polycyclic pathogens, and described the general structure and patterns of epidemics. A few years later, modeling of plant diseases was introduced which, through analysis of information on the host, the pathogen, and their interactions, collected at various points in time and under varying environmental conditions, could predict the course of an epidemic. In 1969, the first computer simulation program of plant disease epidemics was published for the fungal-induced early blight disease of tomato and potato. The simulation program was developed by modeling each stage of the life cycle of the pathogen as a function of various environmental conditions designed to stimulate the pathogen. Since the mid-1970s, disease modeling and computer simulation of epidemics have been developed for many diseases and, together with the newly developed disease monitoring instrumentations, have been used in plant disease forecasting systems. Disease forecasting has become an important component of integrated pest management (IPM), and it has helped reduce the amounts of pesticides applied to crops without reducing yields.

MOLECULAR PLANT PATHOLOGY

Since 1980, great emphasis has been placed on determining the specific molecule and the "genetic connection" of any substance involved in disease development. Because viruses and bacteria are small in size and because a great deal of background information is available on horizons that are difficult to foresee at present. One area, however, to which molecular plant pathology is expected to contribute greatly and to provide tremendous benefits, is the area of detection, identification, isolation, modification, transfer, and expression of genes for disease resistance from one plant to another. Two such resistant genes, one in corn and one in tomato, have already been identified, isolated, transferred into susceptible plants and, when expressed, made the plants resistant. The possibility that molecular plant pathology can modify and combine resistance genes makes likely the future utilization of resistance genes from unrelated plants or from other organisms, and perhaps even the synthesis of artificial genes for resistance for incorporation into crop plants. The practical implications of such developments cannot be overestimated since they are likely to revolutionize control of plant diseases by providing us with cultivars that can resist disease in the presence of the pathogen, without the need to use any pesticides.

DEVELOPMENT OF PLANT PATHOLOGY

As mentioned earlier, plant pathology had its origins in plant pathological observations and studies made by botanists, naturalists, and physicians in Europe in the mid-to late 1800s. Soon after, plant pathological activity shifted primarily to the United States, where it has continued to remain at a high level to date.

The students of the first, self-made, plant pathologists began to be hired as plant pathologists by state agricultural experiment stations, by the federal Department of Agriculture, and by universities at which they taught courses in plant pathology. In 1891, the plant pathologists in the Netherlands formed the Netherlands Society of Plant Pathology and began publishing the *Netherlands Journal of Plant Pathology* in 1895. In 1908, the plant pathologists in the United States organized into the American Phytopathological Society, and they too decided to publish a journal of plant pathology in which they could present the results of their own research and could read about the work of their colleagues. The journal, named *Phytopatholgy*, began publishing in 1911 as an international journal of plant pathology. The Phytopathological Society of Japan was founded in 1916, and its journal began publishing in 1918. In subsequent decades, plant pathologists formed associations and began publishing plant pathological journals in several other countries, for example, Canada (1930) and India (1947). In the second half of the twentieth century, plant pathologists in nearly 50 more countries organized into professional associations; some of them, as in Brazil, published their own national journals, whereas others formed multinational unions, for example, the Latin American Phytopathological Association, or published a regional journal such as *Phytopathologia Mediterranea*. In 1968, an International Society of Plant Pathology was formed, and it held the first International Congress of Plant Pathology in London that same year. As the end of the twentieth century approaches it is probable that most or all countries have one or more plant pathologists, although in many developing countries that person is an administrator of some kind of a professor at a university. Nevertheless, in many parts of the world plant pathology is generally unknown or rarely practiced, and losses from plant diseases in developing countries are still great.

In the mid-1940s, the Rockefeller Foundation, in cooperation with the Mexican government, established a program in Mexico for interdisciplinary research on basic food crops such as wheat, corn, potatoes, and beans. That program was so successful in improving crops and in training personnel in the new technologies that similar Rockefeller Foundation programs were established in Colombia, Chile, and India. It soon became apparent, however, that it would not be possible to have such programs in every developing country; rather, it would be preferable to have a few international centers concentrating on one or a few basic crops. So, with the cooperation of the local governments and funding from the Rockefeller and the Ford foundations, the International Rice Research Institute (IRRI) was established in the Philippines

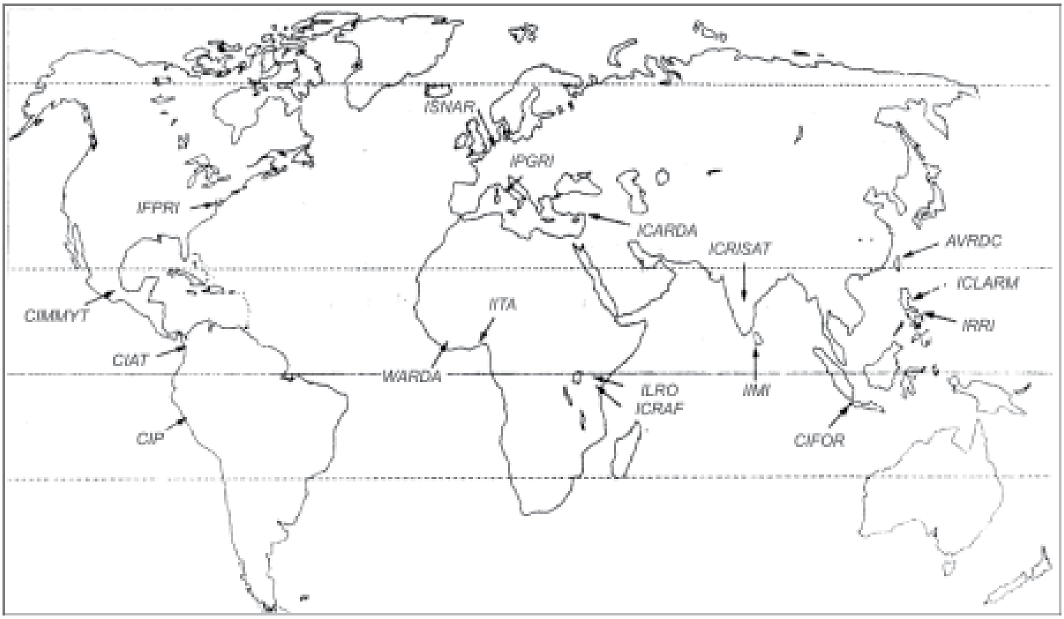

Fig 2.1 : The global agricultural research system.

in 1960, the International Maize and Wheat Improvement Center (CIMMYT) in Mexico in 1966, the International Institute of Tropical Agriculture (IITA) in Nigeria in 1968, and the International Center of Tropical Agriculture (IC TA) in Colombia in 1969.

The success of these centers suggested the need for additional ones. As the finances required to operate the earlier and the new centers were beyond the means of the Ford and the Rockefeller foundations, they, in collaboration with the World Bank, set up a consortium of potential donors interested in financing international agricultural research. The consortium, known as the Consultative Group on International Agricultural Research (CGIAR), consists of wealthy countries, development banks, and other foundations and agencies. The Consultative Group receives help in determining research priorities from a Technical Advisory Committee which consists of 13 scientists and economics. Additional centers established by the Consultative Group include the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India in 1972 and the International Potato Center (CIP) in Peru also in 1972. A similarly operating center but not funded by the Consultative Group, namely, the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, was also established in 1972. More recent centers include the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria, the West Africa Rice Development Association (WARDA) in Gold Coast, and some others (Figure 2.1); IFPRI, International Food Policy Research Institute; ISNAR, International Service for National Agricultural Research; IPGRI, International Plant Genetic Resources Institute; ILRI, International Livestock Research in Institute; ICRAF, International Center for Research Agroforestry; IIMI, International Irrigation Management Institute; CIFOR, Center for International Forestry Research; ICLARM, International Center for Living Aquatic Resources Management.

Each of the above centers includes several plant pathologists working on diseases of the specific crop(s) studied by the center. The contributions of the resident plant pathologists to the study of these diseases and to the quantity of loss may range from 5 to 100 per cent. Plants or plant products may be reduced in quantity by disease in the field, as indeed is the case with most plant diseases, or by disease during storage, as is the case of the rots of stored fruits, vegetables, grains, and fibers. Sometimes, destruction by disease of some plants or fruits is compensated by greater growth and yield of the remaining plants or fruits as a result of reduced competition. Frequently, severe losses may be incurred by reduction in the quality of loss may range frm slight to 100 percent. Plants or plant products may be reduced in quantity by diseases, or by disease during storage, as in the case of the rots of stored fruits, vegetables, grains, and fibers. Some-times, destrucion of some plants or fruits is compensated by greater growth and yield of the remaining plants or fruits as a result of reduced competition. Frequently, severe losses may be incurred by reduction in the quality of plant products. For instance, whereas spots, scabs, blemishes, and blotches on fruit, vegetables, or ornamental plants may have little effect on the quantity produce, the inferior quality of the product may reduce the market value so much that production is unprofitable or a total loss. With some produce, for example, apples infected with apple scab, even as little as 5 per cent disease may cut the price in half; with others, for example, potatoes infected with potato scab, there may be no effect on price in a market with slight scarcity, but there may be a considerable price reduction in years of even minor gluts of produce.

Plant diseases may make plants poisonous to humans and animals. Some diseases, such as ergot of rye and wheat, make plant products unfit for human or animal consumption by contaminating them with poisonous fruiting structures. Many grains and sometimes other seeds and other plant products such as hay, purees, etc., are often contaminated or infected with one or more fungi that produce highly toxic compounds known as mycotoxins. Animals or humans consuming such products may develop severe diseases of internal organs, the nervous system, etc., and may die. Also, many pasture grasses are infected with certain endophytic fungi that grow internally in the plant and, although they do not seem to seriously damage the grass plants, produce toxic compounds which cause severe diseases in the wild and domestic animals that eat the plants. Similarly toxic and sometimes lethal to animals are some grasses infected by nematode-carried bacteria in their seeds; these bacteria are often infected with a virus (bacteriophage) that induces production of compounds very toxic to animals.

SIGNIFICANCE OF PLANT DISEASES

Kinds and Amount of Loss

Plant diseases are of paramount importance to humans because they damage plants and plant products on which humans depend for food, clothing, furniture, the environment, and in many cases housing. For millions of people all over the world who still depend on their own plant produce for survival, plant diseases can make the difference between a happy life and a life haunted by hunger or even death from starvation. The death from starvation of a quarter million Irish people in 1845 and much of the hunger of the underfed millions living in the developing countries today are examples of the consequences of plant diseases. For countries where food is plentiful, plant diseases are significant primarily because they cause economic losses to growers. Plant diseases, however, also result in increased prices of products to consumers; they sometimes cause direct and severe pathological effects on humans and animals that eat diseased plant products; they destroy the beauty of the environment by damaging plants around homes, along streets, in parks, and in forests; and, in trying to control the diseases, people release billions of pounds of toxic pesticides that pollute the water and the environment.

Some examples of plant diseases that have caused severe losses in the past are shown in Tables 2.1 and 2.2.

Plant Diseases and World Crop Production

There are no dependable surveys of numbers of humans living on the earth before the year 1900. It is estimated, however, that there were about 300 million people living on the earth in the year 1 A.D. 310 million in 1000 A.D. 400 million in 1500 A.D. and 1.3 billion in A.D. 1900. During the twentieth century there has been a dramatic explosion in human population. In spite of recent efforts to reduce the rate of population growth, the number of new humans added to world population each year and the additional demands for food, energy, and other resources from our planet are frightening. Thus, world population in 1993 was about 5.57 billion, and at the present rate of 1.70 per cent annual growth, it is expected to be 6.2 billion by year 2000, 7.1 billion by the year 2010, and 8.5 billion by 2025. Currently the world population increases by 1 billion every 11 years.

Paradoxically, the developing countries, in which from 50 to 80 per cent of the population is engaged in agriculture, have the lowest agricultural output, their people are living on a substandard diet, and they have the highest population growth rates (2.64 per cent). Because of the current distribution of usable land and population, of educational and technical levels for food production, and of general world economics, it is estimated that even today some 2.0 billion people suffer from hunger or malnutrition or both.

strigol, which stimulate activation and germination of propagules of some pathogens; and phenolics and sugar released from plant wounds that activate a series of genes in certain pathogens leading to infection.

PENETRATION

Pathogens penetrate plant surface by direct penetration, through natural openings, or through wounds . (Figure 3.3). Some fungi penetrate tissues in one way only, others in more than one. Bacteria enter plants mostly through wounds, less frequently through natural openings, and never directly. (Figure 3.3). Viruses, viroids, mollicutes, fastidious bacteria, and protozoa enter through wounds made by vectors, although some viruses and viroids may also enter through wound made by tools and other means. Parasitic higher plants enter their hosts by direct penetration. Nematodes enter plants by direct penetration and, sometimes, through natural openings.

Penetration does not always lead to infection. Many organisms actually penetrate cells of plants that are not susceptible to these organisms and that do not become diseased; these organism cannot proceed beyond the stage of penetration and die without producing disease.

DIRECT PENETRATION THROUGH INTACT PLANT SURFACES

Direct penetration through intact plant surfaces in probably the most common type of penetration in fungi and nematodes and the only type of penetration in parasitic higher plants. None of the other pathogens can enter plants by direct penetration.

Fungi that penetrate their host plants directly do so through a fine hypha produced directly by the spore or mycelium or through a penetration peg produced by an **appressorium**. The fine hyphae or appressorium is formed at the point of contact of the germ tube or mycelium with a plant temperature, moisture and wind or that reduce host resistance, the longer the environment side would be and the greater the potential amount of disease. If the three components of the disease triangle could be quantified, the area of the triangle would represent the amount of disease in a plant or in a plant population. If any of the three components is zero, there can be no disease.