21st Century Guidebook to Fungi, Second Edition of the online version, by David Moore, Geoffrey D. Robson and Anthony P. J. Trinci

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Chapter 14: Fungi as pathogens of plants

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When early humans gave up their nomadic hunter-gatherer existence and turned to agriculture to solve their food problem they would quickly have been challenged by the fungi. Early farmers must have learned very rapidly that crops are very uncertain resources, prone to variations in weather, fire, floods, weeds, insect pests, and those troubles which came to be referred to collectively as ‘blights’ which were due to various sorts of plant disease.

Great plant losses, caused by any of these factors, can be suffered in natural ecosystems but by bringing the crops together into fields in the first place, the early agriculturalist created ideal conditions for the spread of plant disease. And the more selective his farming, the closer his crops came to be true monocultures, the greater the extent of agricultural losses due to any single agency like a particular plant disease, so in this Chapter we look at fungi as pathogens of plants.

Fungi are the main disease organisms of plants, being responsible for major losses of world agricultural production. Because of the number that exist, we can only give a few specific examples, so we limit these to the headline crop diseases: the Rice Blast fungus (*Magnaporthe oryzae*), the Bootlace or Honey fungus (*Armillaria*), rusts, mildews and smuts (pathogens that

pathogens on their hosts. In the final Sections of the chapter we describe how pathogens attack plants, comparing penetration through stomatal openings with direct penetration of the host cell wall, involving both physical and enzymatic penetration of the host. Finally, we discuss the defence mechanisms of plants and the co-evolution of disease systems which match the genetic variation of pathogens to that of their hosts.

14.1 Fungal diseases and loss of world agricultural production

Standing out among the examples of how damaging a crop disease can be is the Irish famine of 1845/46, which was caused by the failure of the potato crop in Europe because of just one plant disease, the **Potato Late Blight** (caused by a filamentous fungus-like member of the Oomycota, *Phytophthora infestans*). This is an astonishing story of how a crop disease affected the structure of our civilisation and our understanding of nature, while causing the deaths of one in eight of the Irish population.

It is a story which goes far beyond statistics of number of deaths due to starvation, number of people emigrating, or crop losses and reduction in agricultural yield, and you can read that story in more detail in Chapter 2 of the book *Slayers, Saviors, Servants and Sex. An exposé of Kingdom Fungi* by David Moore (2000) [VIEW on Amazon]. But it is a piece of our history which we must read about in the knowledge that even today world agriculture suffers significant losses due to plant disease, despite all our scientific advances of the past 150 years. Hopefully, in that time we have learned enough at least to avoid massive calamities like the Irish famine, and today's losses can be reported in terms of monetary losses. But behind each such statistic there must be personal tragedies in which the lives of individuals and families are changed dramatically.

Although **weeds** are the major cause of crop loss on a global scale, major losses are suffered by agricultural crops due to **insect damage** and **plant diseases**. In rounded (approximate) figures, the world-wide annual production tonnage %age lost to various pests at the start of the 21st century have been estimated as follows:

- losses due to animal pests, 18%;
- microbial diseases, 16% (and 70-80% of these losses were caused by fungi);
- weeds, 34%;
- making a grand total of 68% average annual loss of crop production tonnage (data from Oerke, 2006).

Of course, it is not only fungi that cause plant disease (Fig. 14.1). There are bacteria, viruses, nematode worms (eel worms), aphids and insects as well as fungi. Serious plant diseases are caused by all these other pests, but fungi probably cause the most severe losses due to disease around the world. For one thing there are **more plant pathogenic fungi** than there are plant pathogenic bacteria or viruses. One survey made several years ago in the American State of Ohio came up with the estimate that the State had one thousand diseases of plants caused by fungi, one hundred caused by viruses and fifty due to bacteria. Crop protection measures include **weed control**, which can be managed mechanically or chemically, and the control of animal pests or diseases, which relies heavily on synthetic chemicals. **Pesticide use** has enabled farmers to modify production systems to increase crop productivity while still maintaining some measure of control over the damaging effect of pests. Unfortunately, despite large increases in pesticide use, crop losses have not significantly decreased during the last 40 years.

Crop losses are caused by both biological and physical aspects of the environment that lead to a lower actual yield than the site can be expected to attain (Figs 14.1 and 14.2). The **attainable**

yield is the realistic technical maximum under the best achievable growth conditions. It is generally much less than the **yield potential**, which is the theoretical maximum that cannot be reached under practical growth conditions in the field. Crop losses are best expressed as a proportion of attainable yield but sometimes the proportion of the actual yield is calculated. Pests reduce crop productivity in various ways, for example by:

- **reducing the stand** (that is, the population) of plants (pathogens that kill the host [necrotrophs], like damping-off pathogens that kill seedlings, are examples);
- **reducing photosynthetic rate** (fungal, bacterial, virus diseases);
- **accelerating plant senescence** (most pathogens);
- **shading and 'stealing' light** (weeds, some pathogens);
- **depleting assimilates** (nematodes, pathogens, sucking arthropods);
- **consuming tissue** (chewing animals, necrotrophic pathogens);
- **competition** for inorganic nutrients (weeds).

Crop losses can be quantitative and/or qualitative, and expressed in absolute terms (kg ha^{-1}, or financial loss ha^{-1}, for example) or in relative terms (% loss in production tonnage, for example):

- **quantitative losses** result from reduced productivity giving a lesser yield per unit area;
- **qualitative losses** from pests can result from:
- reduced content of a normal ingredient(s) of the crop,
- reduced market quality (for example miss-shaped, blemished fruit and vegetables),
- reduced storage quality,
- contamination of the harvested product with pests, parts of pests or toxic products of the pests (for example, mycotoxins).

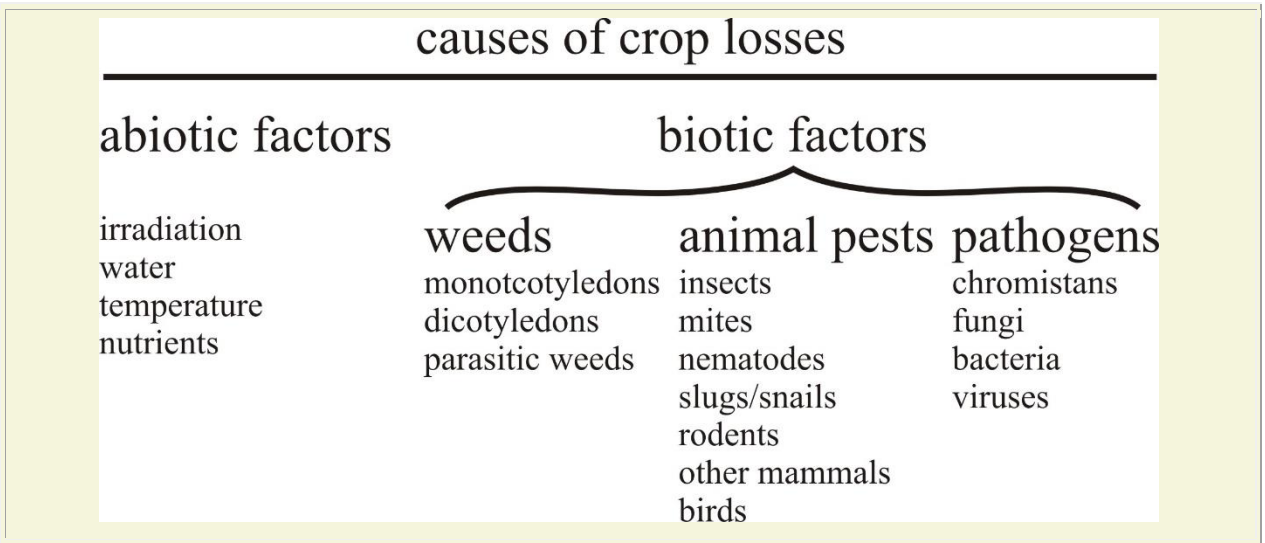

Fig. 14.1. Biological and physical aspects of the environment that lead to a lower actual yield than the site can be expected to attain under ideal circumstances. Modified from Oerke (2006).

Agricultural **survey statistics** make it clear that crop losses directly attributable to fungi are very considerable. Of course, it's changing all the time because, at least in part, losses depend on the weather, but it appears that world agriculture sustains average losses (in terms of monetary value) of around 16% annually as a result of plant diseases. This overall average conceals instances of good news; with disease loss in the 1 to 2% percent range as well as bad news of a season of unusually heavy pest incidence which might involve losses in the 30 to 40% region. Among crops, the total global **potential loss** due to ***all*** pests varied from about 50% in wheat to