Chapter 1

Introduction

1.1 Setting the scene: The importance of plant diseases

Plants are the source of food and fibre for the humans on the earth. Plants constantly suffer from the onslaught of different kinds of pathogenic organisms causing diseases. The causative agents of plant diseases belong to the same groups as those causing disease in animals – pathogenic microorganisms such as fungi, viruses, bacteria, protozoa, and nematodes (Agrios, 2005). Since the dawn of agriculture, plant diseases have been responsible for crop losses, resulting in devastating times of hunger and famine. The estimated total crop loss from diseases, insect pests, and weeds is about 36% of potential worldwide production, of which 14% is attributed to diseases (Agrios, 2005). It has rightly been stated that at least 10% of global food production is lost due to plant diseases. Catastrophic plant diseases exacerbate the current deficit of food supply in which at least 800 million people are inadequately fed and 1.3 billion live on less than $1 a day (Strange and Scott, 2005). Plant diseases significantly influence world economy. According to the FAO estimates, plant diseases could cost the US alone $33 billion per year (Maor and Sirashu, 2005). These facts explain why diseases affecting plants have been feared as much as human diseases and war throughout history.

Plant diseases could inflict quite a few famines on humans. The Irish Famine in the 1840s that resulted from a potato late blight epidemic caused by the fungus *Phytophtora infestans* is one such example. About a million people died of starvation and more than a million attempted to emigrate out of Ireland (Strange, 2003). There have been other disasters caused by plant diseases such as the Great Bengal Famine of 1943 (Padmanabhan, 1973) and the southern corn leaf blight epidemic of 1970-1971 in USA (Ullstrup, 1972). In the former, about 2 million people died for high dependence of the population on a single crop, i.e. rice, which was attacked by the fungus *Cochliobolus miyabeanus*. In USA, the corn (maize) crop was completely destroyed by another fungus from the same genus, *Cochliobolus heterostrophus*. As alternative sources of nutrition were plentiful, no one died due to the epidemic in USA. But the effect of the crop failure on the agricultural economy was severe. A number of such epidemic instances exist which could underline with brutal clarity the importance of plant diseases to humans (Table 1.1).

Table 1.1: Some more examples of colossal losses caused by plant diseases*

Disease	**Location**	**Comments**
Fungal		
1. Powdery mildew of grapes	Worldwide	European epidemic (1840s-1850s)
2. Downy mildew of grapes	USA, Europe	European epidemic (1870s-1880s)
3. Downy mildew of tobacco	USA, Europe	European epidemic (1850s-1860s), Epidemic in North America (1979)
4. Chestnut blight	USA	Destroyed almost all American chestnut trees (1904-1940)
5. Dutch elm disease	USA, Europe	Destroying American elm trees (1918 to present)
6. Coffee rust	Asia, America	Destroyed all coffee in south-east Asia (1870s-1880)
Viral		
7. Citrus tristeza	Africa, America	Millions of trees being killed
Bacterial		
8. Citrus canker	Asia, Africa, Brazil, USA	Eradicated millions of trees in Florida in 1910s and again in 1980s
Phytoplasmal		
9. Peach yellows	Eastern USA, Russia	10 million peach trees killed
10. Pear decline	Pacific coast states, Canada, Europe	Millions of pear trees killed (1960s)

* Modified from Agrios (2005).

1.2 The Plant: Tomato

The tomato (*Solanum lycopersicum* L.; Synonym: *Lycopersicon esculentum* Mill.) belongs to Solanaceae family and it is closely related to potato, chilli, eggplant and tobacco. It is an annual plant typically reaching to 1-3 m (3 to 10 ft) in height, with a weak, woody stem (Plate 1.1). The leaves are 10-25 cm long, pinnate, with 5-9 leaflets, each leaflet up to 8 cm long, with a serrated margin; both the stem and leaves are densely glandular-hairy. The flowers are 1-2 cm across, yellow, with five pointed lobes on the corolla; they are borne in a cyme of 3-12 together.

A

B

Plate 1.1: Tomato is a high value crop in the world. **A.** A tomato plant with unripe fruits; **B.** Harvested ripe fruits of tomato

Tomato is one of the world's major vegetable crops. It is used as a fresh vegetable and can also be processed and canned as a paste, juice, sauce, powder or as a whole. It is an excellent source of many nutrients and secondary metabolites that are important for human health: folate, potassium, vitamins A, C and E, flavonoids, chlorophyll, β-carotene and lycopene (Wilcox et al., 2003). Lycopene is a carotenoid, and is the pigment principally responsible for the distinctive red color of ripe tomato and tomato products. Several epidemiological studies have suggested that a high consumption of tomatoes and tomato products containing lycopene may protect against cardiovascular diseases and reduce risk of several types of cancer. Lycopene is known to possess a high antioxidant activity.

The high demand for tomato makes it a high value crop that can generate much income for farmers. Tomato is best adapted to warm and dry environments, but during the hot-wet season, yields are low due to poor fruit-setting caused by the high temperatures, as well as many severe disease problems.

1.3 The Disease: *Fusarium* wilt of tomato

One of the main constraints of tomato cultivation today is losses caused by diseases, and *Fusarium* wilt is one of the most prevalent and damaging diseases of tomato world wide (Agrios, 2005). In his classic monograph, Walker (1971) noted the first published description of *Fusarium* wilt of tomato by Massee (1895) and subsequent reports of its occurrence, often with severe losses, in many parts of the world. The disease is most destructive in warm climates and warm, sandy soils of temperate regions. The disease causes great losses, especially on susceptible varieties and when soil and air temperatures are rather high during much of the season. Infected plants become stunted and soon wilt and finally die. Occasionally, entire fields of tomatoes are killed or damaged severely before a crop can be harvested. *Fusarium* wilt is responsible for severe crop losses in the field and commercial greenhouses (Benhamou et al., 1998).

1.3.1 Symptoms of *Fusarium* wilt

When seedlings are infected by the fungus, growth of the seedlings is reduced; the leaves curve downward and wilt. Young plants usually die when they are infected at an early stage (Jones et al., 1997). The first visual symptom of *Fusarium* wilt is yellowing of the lower leaves, often only on one side of the plant (Mace et al., 1981). Subsequently, the leaves show epinasty caused by drooping of the petioles. More commonly, however, in older plants, vein clearing and leaf epinasty are followed by stunting of the plants, yellowing of the lower leaves, occasional formation of adventitious roots, wilting of leaves and young stems, defoliation, marginal necrosis of the remaining leaves and finally death of the plant (Plate 1.2). When the fungus enters the plant, it grows inside the vascular tissue that becomes dark and damaged. The discoloration is present in the roots as well as in the stem and branches (Jones et al., 1997). In cross sections near the base of the infected plant stem, a brown ring is evident in the area of the vascular bundles. The upward extent of the discolouration depends on the severity of the disease (Agrios, 2005). Vascular browning has long been noted as a diagnostic symptom of wilt diseases (Beckman, 1987).

Plate 1.2: Leaf yellowing wilting symptoms of *Fusarium* wilt on tomato plant. Inset: Vascular browning on stem.

1.3.2 The Pathogen: *Fusarium oxysporum* f. sp. *lycopersici*

The causal agent of *Fusarium* wilt on tomato is *Fusarium oxysporum* f. sp. *lycopersici* (Sacc) Snyd & Hans (Chambers and Corden, 1963). Henceforth the pathogen is referred to as *Fol*. This devastating pathogen belongs to Deuteromycetes (imperfect fungi) and is soilborne with a high level of host specificity. There are more than 120 described formae speciales and races within the species. Together they cause diseases on a wide range of agricultural crops (Correll, 1991; Agrios, 2005). The mycelium of the fungus is colourless at first but with age it becomes cream coloured, pale pink or some what purplish (Plate 1.3). *Fusarium oxysporum* produces three kinds of asexual spores: microconidia, macroconidia and chlamydospores. Microconidia are small, 5-12 x 2-3 μm, and produced abundantly at the end of mycelium branches in all conditions. Macroconidia have three to five cells and pointed ends. The size varies from 27-60 x 3-5 μm. The macroconidia are produced on the surface of dead plant tissue (Jones et al., 1997; Agrios, 2005). Chlamydospores are round spores with thick walls that can survive in the soil for a long time. They are usually produced at the end of old mycelia in decaying plants (Nelson et al., 1981). The pathogen is spread worldwide and once the soil is infested it is difficult to eliminate the pathogen since it survives in the soil for long periods (Watterson, 1986).

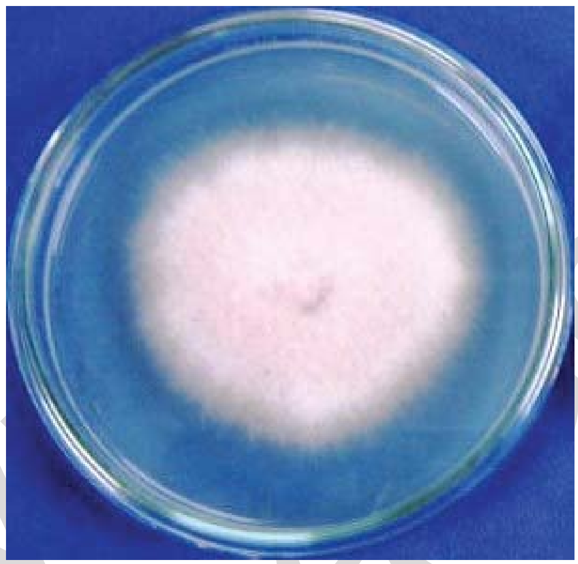

Plate 1.3: Growth of *Fusarium oxysporum* f. sp. *lycopersici* on potato dextrose agar medium

1.3.3 Development of disease and life cycle

The pathogen is a soil inhabitant. Growth and survival of *Fol* is favoured by dry soil, but after infection the spread of the pathogen inside the plant is favoured by moist soil and a high transpiration (Nelson et al., 1981). The fungus spreads between fields with contaminated soil on plants or farm equipment, with seeds or water. In the periods between tomato productions, the fungus survives as mycelia, micro- or macroconidia on plant debris or as dormant chlamydospores in the soil.

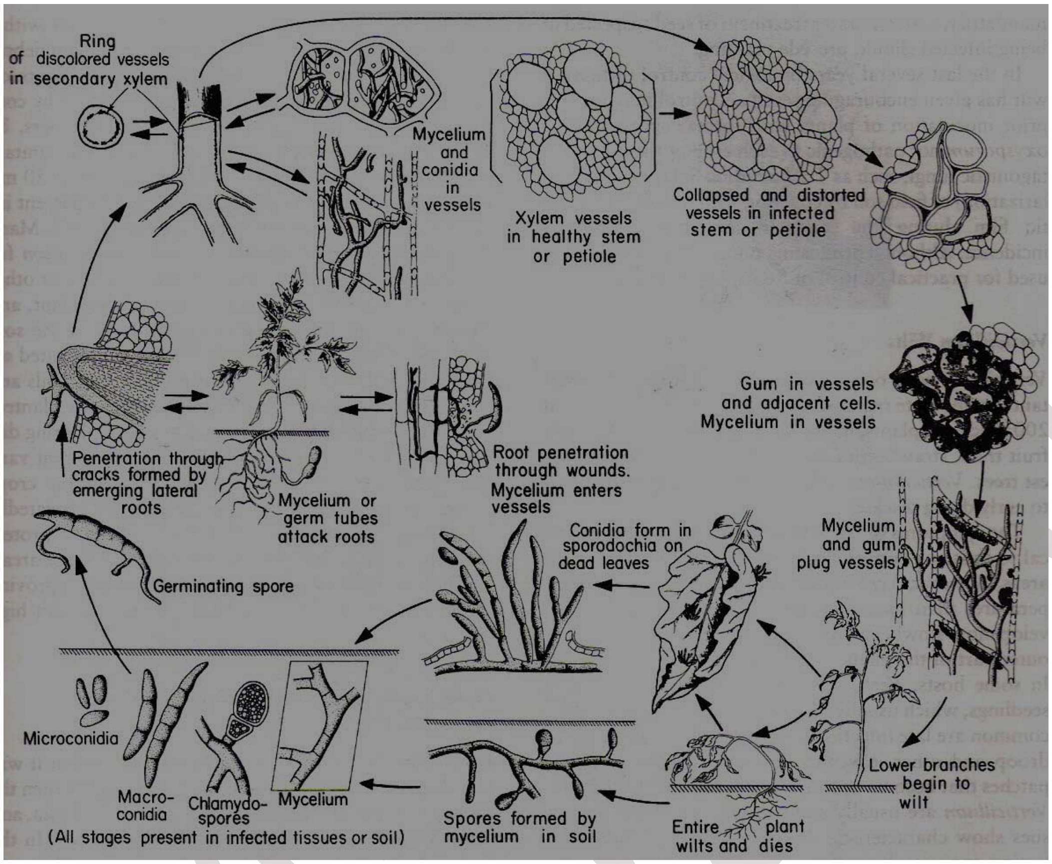

Figure 1.1: Life cycle of *Fusarium oxysporum* f. sp. *lycopersici* on the host (tomato) and soil. Adapted from Agrios (2005).

When new plants grow in the contaminated soil the spores are stimulated to germinate. A germinating chlamydospore forms conidia or new hyphae (Mace et al., 1981). The germ tube of spores or the mycelium penetrates root tips directly or enters the roots through wounds or at the point of formation of lateral roots. The mycelium advances through the root cortex intercellularly, and when it reaches the xylem vessels it enters them through the pits. The mycelium then remains exclusively in the vessels and travels through them mostly upward toward the stem and crown of the plant (Agrios, 2005). While in the vessels, the mycelium branches and produces microconidia, which are detached and carried upward in the sap stream. Microconidia germinate at the point where their upward movement is stopped. The mycelium penetrates the upper wall of the vessel, and more microconidia are produced in the next vessel. The mycelium also advances laterally into the adjacent vessels penetrating them through the pits.