Communicable Plant Diseases – Introduction

The British Society for Plant Pathology (BSPP) have put together this presentation to fulfil the basic requirements of all the exam specifications in the UK that teach about *communicable plant diseases* at GCSE level.

The material is also suitable as an introduction/recap for A-level students as well (currently OCR specification only) but you are encouraged to also use Part 2 of the presentation which gives more detail about the nature of plant cell responses to pathogen attack.

You are welcome to adapt the slides in this presentation to suit your teaching style and specific curriculum requirements.

These notes are designed to support you in the delivery of this presentation giving a commentary for each slide.

Slide 2
Estimates vary widely but there are well in excess of 50,000 plant diseases around the world. The effects of many are **damaging** to the appearance and/or yield of plants and they can be **deadly** to plants and consumers of these plants. Pictured are a few graphic examples of different plant diseases. (1) A fungus called *Fusarium* (phew-zer-rium) infecting maize kernels (2) A potato plant showing the effects of late blight (the cause of the Irish potato famine), more about that later (3) Trees also suffer infections – these Beech trees are infected with a disease called Bleeding Canker (note the white fungal hyphae on the trunks) caused by *Phytophthora cambivora* (Phy-top-thora) (4) a common disease of soft fruits around the world, *Botrytis cinerea* (Bo-try-tis sin-er-rea), pictured here on grapevine.

Slide 3
Animals including humans suffer from diseases; these are caused by any of 3 micro-organisms: bacteria, fungi and viruses. Two examples of each follow (Slides 4, 5 and 6).

Slide 7
The same types of micro-organism (bacteria, fungi and viruses) cause diseases in plants. Although it is important to note that animal diseases do not infect plants and vice-versa.

Slide 8
The disease causing agents in plants are called plant pathogens and the discipline involving their study is known as plant pathology.

Plant pathogens cause yield losses in plants (affecting a farmer's yield and the price of the product to the consumer, issues that relate to Food Security). However, most plants are resistant to most diseases.

Slide 9 and 10
Named examples of bacterial diseases of plants. For more details about Ring Rot and Crown Gall disease see BSPP's Pathogen Information Sheets. Typical symptoms includes yellowing (chlorosis), decay and rot, along with malformed growths or galls.

Slides 11 and 12
Named examples of fungal diseases of plants. For more details about Black Sigatoka, Powdery Mildew, Black Spot disease (Rose) and Ash Dieback see BSPP's Pathogen Information Sheets.

Slides 13 and 14
Named examples of viral diseases of plants. For more details about Tobacco Mosaic Virus see BSPP's Pathogen Information Sheets. Viral diseases may cause stunted growth, chlorotic flecks or patches on the leaves, and leaf curling or a combination of these.

Slide 15
PLENARY – Recapping the fact that bacteria, fungi and viruses cause diseases in both animals and plants. Fungi are eukaryotic organisms; bacteria prokaryotic organisms; viruses best described as non-cellular packaged nucleic acid ('a splinter of life'). The plant virus pictured here is another example of TMV symptoms (picture not used earlier)

Slide 16.
So far we have limited our discussions to the 3 main groups of micro-organisms: bacteria, fungi and viruses. Another eukaryotic Kingdom exists – the Protoctista or Protists – which groups together unicellular algae, protozoa, slime moulds, and water moulds. In health terms, 2 organisms of huge significance fall into this group – in animals the malaria parasite (*Plasmodium vivax*), and *Phytophthora infestans* the cause of the Irish Potato famine. Pictures of both follow in the next 2 slides.

Slide 17.
Parasitised blood cells are shown in the main picture (stained dark blue), with a blood-filled mosquito in the inset.

Slide 18.
The Irish Potato Famine of 1845-46 was caused by the oomycete *Phytophthora infestans* (classified as a member of the Protoctista). Pictured are many asexual spore sacks, sporangia, produced by this organism – both empty and full sporangia are visible. Empty ones have already released their zoospores. Zoospores are a key element in the dispersal and spread of this disease.

The remaining slides include a discussion of the historical context of plant pathology, with some specific diseases looked at in a little more detail. The presentation concludes by bringing us up-to-date with an overview of the key ways in which the control of plant disease is achieved, and human involvement in this process.

Slide 19
For as long as humans have grown crops, they have been battling against plant diseases. The diseases reduce yield or destroy a crop completely.

Slide 20
Mildews and blights (plant diseases mentioned earlier) were mentioned in several books of the New Testament (Christian bible). There are also other ancient texts which refer to plant diseases: a Sumerian clay tablet (1700 BC), Indian literature (1500 BC) and the literature of the Aztec Maya and Incas all include reference to plant disease.

Slide 21
Once it was thought that gods and goddesses controlled natural events. The Greek goddess of the harvest was Demeter, while the Roman equivalent was Ceres. People thought that a crop failure was caused by the Gods and so sacrifices were made in honour of the Gods to appease them. In fact plant disease was likely to be the cause of the crop failure.

Slide 22
The Festival of Robigalia is one such instance and it included sacrifices in honour of the Roman god Robigus. The 'red' fungus (stem rust) they were seeking protection against is still a problem today (see https://www.wired.com/2010/02/ff_ug99_fungus/) and is pictured in the next slide

Slide 23
Wheat Stem Rust (*Puccinia graminis*) is a fungal disease which produces masses of reddish spores on the leaves, stems and even the ears of mature wheat plants.

Slide 24
So far we have focussed solely upon the direct effects of the disease causing organisms and the symptoms they cause. However, there is another problem with some plant diseases, namely the production of toxins (chemicals) by the micro-organism within infected plant tissues. These toxins can have dramatic and deleterious effects upon human health and livestock consuming food products.

Slide 25
Describes and pictures the effects of one such disease first recorded in about the 11th Century. The condition was known first as Holy Fire (in Latin, *Ignis Sacer*), referring to the burning sensation experienced by people who had consumed infected rye grain. The symptoms are caused by consumption of ergots (structures produced by the fungus) that develop instead of grain and are mixed with the grain and milled into the flour. It was also known as St. Anthony's Fire after hospitals in honour of St. Anthony were established to treat the afflicted. Relief was provided probably because the hospitals did not serve bread containing ergots! It was the 17th Century however before ergotism was shown not to be an infectious disease but the link between the presence of a fungus in infected rye and the symptoms was not made for another 200 yrs (next Slide).

Slide 26
The fungus causing the problem was identified as *Claviceps purpurea*. It produces over-wintering (survival) structures, black in colour and slightly larger than grain, called sclerotia (more commonly known as ergots). Within these structures are many secondary metabolites that cause the symptoms

associated with St. Anthony's Fire. So when the grain is turned into flour or fed to livestock, the chemicals enter the food chain causing the outbreaks.

Slide 27

Ergotism has killed many thousands of people over the years although modern milling methods, and more advanced combine harvesters, will now filter out the ergots from 'good grain.' For a fascinating account of the incidence of the disease since 1900 see this short paper available through open access in Toxicology and Industrial Health (http://doi.org/10.1177/0748233711432570). Modern examples of ergotism tend to be limited to areas with lower socioeconomic conditions and simpler farming methods (eg. India and Sub-Saharan Africa).

Slide 28

We will now focus on another disease with a prominent place in history. The Irish Potato Famine of 1845/6 killed an estimated 1.5 million people, and forced another 2 million to emigrate. The cause was the Late Blight pathogen, *Phytophthora infestans*. Its name in Greek literally means Plant Destroyer! (*Phyto* – plant; *-phthora* – destroyer).The disease infects leaves, stems and tubers and it destroyed the potato harvest in Ireland in 1845. A memorial to those affected depicting frail and starving people is located on the quayside in Dublin from where many fled to new lives in America and Canada.

Slide 29

Against a back-drop of the figures for the Irish population between 1600 and 2000 are some more details about the famine. It is an example of a disease that was brought into a new country from its country of origin and flourished. As international trade routes developed cases like this became more common. The population of Ireland is yet to recover to pre-1845 levels, even 150 years after the outbreak (a BSPP information sheet specifically about this disease is available from www.bspp.org.uk/outreach).

Slide 30

A simple timeline to show our growth in knowledge about Plant Diseases. Beginning with Anton de Bary's pioneering work with Potato Blight (1863), almost 20 years before Pasteur's germ theory. By the end of the 19th century it had become clear why plants got sick: due to fungi, bacteria and viruses.

Slide 31

Over the next 100 years scientists focussed their efforts on trying to control and prevent plant diseases. These endeavours can be broken down into 3 areas – chemical control, cultural control and genetic control (each described in more detail in the following 3 slides, #32/33/34).

Slide 32

The most widely used method of control against plant disease is the application of agrochemicals to either kill the pathogen causing the disease or protect against the disease (prophylactic). The control of Black Sigatoka for example sees approximately 40 applications of fungicides in a year. Concerns over human health with persistence of these chemicals in the food chain and the wider environment is resulting in tighter rules and regulations around their application. The diseases themselves have also evolved resistance to the active ingredients so reducing their effectiveness.

Slide 33
Scientists have known for many years that the elimination of plant waste and the so-called 'green bridge' between crops is an important method to prevent disease carry-over from one year to the next. As a result stubble burning was commonplace up until the 1990's when pollution concerns led to it being banned in the UK. The incidence of many diseases can be reduced by 'ploughing'in' weeds/plant residues. Any method which sees such changes to farming methods, is known as cultural control.

Slide 34.
Since early Agriculture farmers often 'selected' the 'best looking' / tallest / highest yielding plants from the crop for sowing in future seasons. Following Mendel's famous work on peas in the mid 1860's, and the knowledge of inheritance that came from this work, scientists (plant breeders) began to concentrate on breeding for plant disease resistance. In the early 1900's pioneering work in Cambridge was led by Sir Professor Rowland Biffen at the Plant Breeding Institute that focussed on yellow rust resistance. Pictured are 3 different varieties of wheat, that have all been infected by the fungus yellow rust. The variety on the left is resistant (with no symptoms of disease); the variety on the right is susceptible – covered in yellow spores from the fungus. The variety in the middle is also resistant, but you can see a flecking on the leaf surface – a plant response to limit the spread of the fungus inside the plant. A single resistance gene may change a plant from susceptible to resistant but it is often more complex than this, involving many genes and being dependent on the allelic variation.

Slide 35
Our previous slide referenced the role of plant breeders in creating new varieties. Here is a **simplified overview** of that process, crossing together 2 varieties of wheat, A and B, seeking improved disease resistance in a high-yielding bread wheat. In breeding plants you mix the pollen from one plant with the female parts of a plant of the same species (that may have had the anthers, the source of the pollen, removed) to ensure cross- not self-pollination.

Slide 36
We will finish this introduction to Plant Diseases with a look at the Disease Triangle. Just what does it take for a plant to become diseased? It is the interaction of 3 different factors – (1) the host (the plant) needs to be susceptible to the disease; (2) the pathogen (the bacteria/fungi/oomycete or virus) must be able to overcome the plant's defences; (3) the environment in some way must tip the balance in favour of the pathogen (maybe by providing optimal conditions for its growth, or by reducing the effectiveness of the plants defences). All these factors interact, its complex.

Slide 37
In fact we now think of the disease triangle as a pyramid – with a 4th factor involved, the role of humans. The migration of people and plants will usually involve humans and this has led to the spread of different diseases around the globe. A desire for uniformity and the need to increase food production has seen monoculture become widespread (the norm), so that when a disease becomes established on one plant, because all the others around it are very, very similar it is easier for the disease to spread. Polyculture would reduce disease spread. Humans have introduced diseases and their vectors into new locations, and the choice of growing practices (how far apart plants should be

spaced, and the effect this has upon humidity levels and subsequent disease development) all demonstrate human influence.

Slide 38
But whether it is plant or pathogen that ultimately wins, will often be decided by a variety of factors that humans can't influence – the environment.

Slide 39
We finish with reference to human influence on the triangle itself. Humans can influence (1) the host - plant breeders can control whether the host is susceptible (2) the pathogen – can potentially be sprayed by farmers to eliminate it, and (3) many aspects of the environment around a plant – moisture levels, soil nutrient levels, acidity levels even humidity – are influenced by farming decisions alongside prevailing weather conditions.

Slide 40
For a closer look at the interaction between plants and their diseases you are encouraged to view/download the follow-up PowerPoint presentation (when it becomes available). Pictured in this slide are the spores of the yellow rust fungus (referenced in Slide 34) bursting out of a pustule on the leaf surface of a wheat plant viewed under a scanning electron microscope (SEM).