Why are Plant Diseases so Important for Biodiversity

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The Wyre Forest Study Group has been very active in exploring the plant pathogens that occur within the Forest. This paper is intended to introduce the terminology used within plant pathology (the science of plant diseases) and describe how plant pathogens spread and may become epidemic. Whilst they are not good for crop productivity, plant pathogens play an important part in maintaining functioning ecosystems. Their role is discussed here.

Pest &Disease (P&D) terms:

- **Pest** – an animal that causes damage to plants e.g. insect, mite, nematode
- **Vector** – an animal that carries and transmits a micro-organism that can cause plant disease
- **Pathogen** – an organism that causes disease in plants e.g. fungi, water-mould, bacteria, viruses, mycoplasmas
- **Symptom** – the signs by which we see that a pathogen is present in that it affects growth or the appearance of the plant
- **Disease** – the collection of **symptoms** that are caused by a pathogen
- **Host species –** the plant species, or range of plant species, that the pest can attack or the pathogen can infect
- **Epidemic** – recognised in terms of the number of plants infected and the severity – it often describes a rapid increase in disease levels across a population

Pathogens, and other organisms that feed on plants, have different ways of deriving their nutrition. Biotrophs feed off living cells. They have specialised, nutrient absorbing structures, such as haustoria, that grow inside the plant cells. These pathogens are usually quite specific as to which host they can invade. By contrast, necrotrophs kill off the cells and then feed off the contents. They generally have a wider host range *e.g. Botrytis cinerea* with which we are familiar as the grey mould that softens and covers soft fruit such as strawberries. Saprotrophs only feed off tissue that is already dead and so are not strictly plant pathogens but rather decomposers. Some necrotrophs can also live as saprotrophs and they are termed facultative as they can feed by more than one method. Obligate organisms can only use one of the above methods.

Symptoms

Symptoms help in the diagnosis of the disease and in the identification of a pathogen. For instance, if the whole plant is affected, with symptoms appearing suddenly, showing a wilt symptom or die-back, then there is likely to be a root problem *e.g. Phytophthora* root rot, or a blockage of the vascular system *e.g. Verticillium* wilt of Chrysanthemum.

Fungal and some bacterial diseases cause leaf spots or tip necrosis *e.g. Phytophthora ramorum* on rhododendron, *Diplocarpon rosae* (Rose Black spot disease) and *Phytophthora infestans* (late blight of tomato).

Other pathogens may be characteristic because you can see the organism and these have been recorded in the Wyre Forest *e.g.* powdery mildew – white on the upper leaf surface, downy mildew – white on the underside of the leaf, rust – yellow/orange/white pustules on leaves and stems.

Insects can cause characteristic damage to leaves *e.g. Phytomyza ilicis* - Holly Leaf Miner where larval feeding tracks are seen in leaves, Italian Alder leaf skeletonised by alder leaf beetle (*Agelastica alni*) (Figure 1).



Figure 1. Skeletonised leaf of Italian Alder *Alnus cordata* by Alder Leaf Beetle *Agelastica alni*

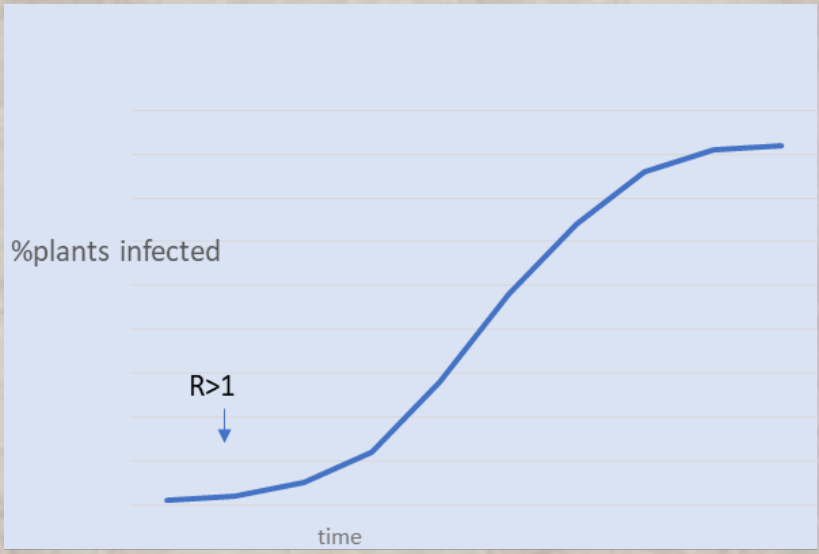


Figure 2. Generalised S- shaped curve of the epidemic spread of a plant pathogen

Some organisms disrupt the hormones in the plant producing distinctive symptoms *e.g.* Currant Blister Aphid.

Nutrient deficiencies may be confused with disease. These deficiencies are most obvious on leaves. For example, characteristic leaf symptoms may be: nitrogen deficiency – pale upper leaves, lower leaves yellow; potassium deficiency – yellowing at the tips and edges; or iron deficiency – yellow leaves with greener veins. A yellowing of leaves is called chlorosis. Viruses can also cause similar symptoms to the iron deficiency *e.g.* Tomato Mosaic Virus.

Pest and disease spread.

Pests and pathogens may be spread: by wind *e.g.* as in Ash Dieback disease; rain and splash dispersal *e.g.* Potato Blight disease, soil and irrigation water *e.g.* Pythium Damping-off disease of seedlings, or by animal vectors *e.g.* Aphid transmission of viruses. They can also enter a plant through wounds, including those made during pruning and grafting.

Severe damage happens in crops when disease epidemics or pest outbreaks occur. They may also occur in natural habitats when the delicate balance in the ecosystem is disrupted.

The spread of a disease such that it becomes an epidemic depends upon:

- Infection rate (that is how many other plants are infected from one individual plant– it is a characteristic of the individual pathogen) the "R number",
- Latent period (time between infection of plant and when infection can spread from it), and
- How long the plant remains infectious.

So, the spread often follows an S-shaped curve *i.e.* slow infection until many spores are being produced on infected plants and the epidemic then spreads quickly. The rapid spread is followed by a slowdown in new infections because most plants are already infected (Figure 2).

An example of an epidemic with which we are all now familiar is Ash Dieback (Figure 3). This is caused by a fungus. In the UK it was first called *Chalara fraxinea* but now we know more about it, the name *Hymenoscyphus fraxineus* is used. It is thought to have originated in East Asia, with the first European record in Poland in 1992. Its presence in the United Kingdom was confirmed in 2012 and it may have arrived on tree imports or it may have been blown in the wind across the North Sea. It is estimated that there are 125 million ash trees in woodlands and between 27-60 million ash trees outside of woodlands in the UK, plus potentially 2 billion saplings and seedlings in woodlands and non-woodland situations (Defra, 2019) and all these have the potential to be infected by the pathogen.

It will not be possible to stop the spread of Ash Dieback now as the host tree is so widespread, and because the pathogen is airborne. However, where it is possible



Figure 3 Ash Dieback symptoms on *Fraxinus quadrangulata*

to stop an epidemic the disease has to be controlled before it reaches that point in the curve (Fig 2) where the increase in numbers of plants infected becomes very fast. This may be done in horticultural situations by stopping any infection in the first place (exclusion) or by removing infected plants before they can infect others (eradication). Pests and pathogens become problematic in agriculture when there are monocultures of plants which are uniform in their susceptibility. Then, all that mass of host plants allows the pest or pathogen to reproduce.

Pests are pathogens and may arrive from other countries, like the Ash Dieback pathogen. The resistance in the local population of new hosts is low or non-existent as they have not been exposed previously. Also, conditions change, making the environment more favourable to new pests and diseases, and this seems to be happening as the climate changes. Adverse conditions are also likely to cause the plants to be stressed and physiologically unhealthy, making them more susceptible.

To reduce the risk of pests and pathogens being introduced on plant imports from abroad, and then spreading, the Government has policies on Plant Biosecurity. This term refers to "a set of precautions that aim to prevent the introduction and spread of harmful organisms" (UK Government, 2023). These precautions and actions include international border controls to inspect plants and plant material, certifying health when selling plants through using Plant Passports, employing hygiene procedures on the nursery so that the risk of introducing unhealthy material is minimised, and controlling the spread of outbreaks if they occur. There is a significant risk of new pests and pathogens being introduced into Great Britain on imports of plant or plant products *e.g.* on wooden pallets or fruit.

Surveying for pests and diseases is carried out nationally, including using citizen science through *apps* such as TreeAlert, to see if new problems are occurring or how far they have spread.

Policy makers, scientists and growers are trying to develop social, economic and environmental resilience to the effects of pests and disease impacts. The components of resilient systems include planting a diverse range of crops and resistant varieties, introducing biosecurity and hygiene routines, and maintaining soil and pollinator health.

However, these epidemics do not just occur in farming. It is also crucial that we protect biodiversity and balanced ecosystems. Having said that, we need to recognise that the animals and pathogens which feed on plants are also part of biodiversity and are essential parts of natural ecosystems.

An "ecosystem" may be described as a single environment in which every living (biotic) organism and non-living (abiotic) factor are interacting *e.g.* a forest, or the human gut. For comparison, a "habitat" is specific to a population. Wherever that population lives is its habitat.

Pathogens have had long relationships with their host species. Viruses, possibly, evolved along with the first single cells. Very recently, a fungal plant pathogen from 407 million years ago, the earliest so far discovered, has been found from Scotland and named *Potteromyces asteroxylicola* after the great mycologist and children's author Beatrix Potter.

The relationships between plant hosts and diseases may be of complex, interlinked life cycles. We are seeing an example of this through the fascinating work on Acute Oak Decline. This is showing that the disease is caused by the interaction of several bacterial

species, mediated by a beetle (Forest Research, 2023).

Most research has been done in agriculture and there is limited research on pathogens in natural ecosystems. We need to encourage more of it. That is one of the reasons why the work of the Wyre Forest Study Group is so important.

Professor J. L. Harper (1977) was one of the first to call for research into plant pathogens in natural ecosystems. He said, "the dynamics of ecosystems cannot be understood without appreciating the role of pathogens and animal predation on plants."

Within natural ecosystems, where host and pest or pathogen co-evolve, their inter-relationships tend to be more balanced than in agricultural systems. The host can evolve to become resistant but then the pathogen changes to become virulent again in a step-for-step process.

In these ecosystems, pathogens are an important control in the growth of plant populations. For instance, the Janzen-Connell effect (first proposed for tropical forests) describes the lower survival of seedlings when they grow near their parent tree. So, when seedlings are at a high density, growing around the plant from which the seeds have fallen, the pathogens and host-specific herbivores are able to spread readily between these hosts. The infections then reduce the density of the host species. The conclusion of this is that the herbivores and pathogens, by thinning dense host populations, stabilise complex ecosystems allowing many species to grow, rather than allowing a single species to become dominant. This does depend, though, on other environmental factors and they may allow dominance of a few species.

Another way in which pathogens can regulate the composition of plant populations is when resistant hosts thrive and dominate, because the pathogen infects only the susceptible plants. The infected, susceptible hosts may have reduced vigour and competitiveness, lower seed production, and even be completely lost. This affects the diversity of the population and of the ecosystem.

Professor David Ingram (2021) champions the need to learn more about pathogens in natural ecosystems. Plant pathogens and "pests" are integral and valuable parts of ecosystems. Indeed, some of them need our help through conservation. This can be appreciated, for example, in the "Rust Fungi Red Data List and Census Catalogue for Wales" which shows the rarity of some native, rust pathogen species. It notes that, of 225 taxa of rust fungi recorded in Wales, three are probably extinct and 39 are threatened with extinction. For example, the rust fungus *Puccinia bistorta* is critically endangered on the Common Bistort *Persicaria bistorta*. Natural England has listed a range of fungi which are "Species of Conservation Concern" as part of its Biodiversity Action Plans.

Knowledge gained from the comprehensive, plant pathogen surveys in the Wyre Forest can contribute hugely to our understanding of the prevalence and diversity of these organisms in our ecosystems. When surveys are carried out in successive years, they can also describe the changes that are occurring in these ecosystems which will be key to our understanding of their resilience or vulnerability. Happy identifying.

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