PAPER DSE 4: PLANT PATHOLOGY

PLANT DISEASE EPIDEMIOLOGY

Plant disease epidemiology is the study of disease in plant populations. Much like diseases of humans and other animals, plant diseases occur due to pathogens such as bacteria, viruses, fungi, oomycetes, nematodes, phytoplasmas, protozoa, and parasitic plants. Plant disease epidemiologists strive for an understanding of the cause and effects of disease and develop strategies to intervene in situations where crop losses may occur. Typically successful intervention will lead to a low enough level of disease to be acceptable, depending upon the value of the crop.

Plant disease epidemiology is often looked at from a multi-disciplinary approach, requiring biological, statistical, agronomic and ecological perspectives. Biology is necessary for understanding the pathogen and its life cycle. It is also necessary for understanding the physiology of the crop and how the pathogen is adversely affecting it. Agronomic practices often influence disease incidence for better or for worse. Ecological influences are numerous. Native species of plants may serve as reservoirs for pathogens that cause disease in crops. Statistical models are often applied in order to summarize and describe the complexity of plant disease epidemiology, so that disease processes can be more readily understood. For example, comparisons between patterns of disease progress for different diseases, cultivars, management strategies, or environmental settings can help in determining how plant diseases may best be managed. Policy can be influential in the occurrence of diseases, through actions such as restrictions on imports from sources where a disease occurs.

In 1963 J. E. van der Plank published "Plant Diseases: Epidemics and Control", a seminal work that created a theoretical framework for the study of the epidemiology of plant diseases. This book provides a theoretical framework based on experiments in many different host pathogen systems and moved the study of plant disease epidemiology forward rapidly, especially for fungal foliar pathogens. Using this framework we can now model and determine thresholds for epidemics that take place in a homogeneous environment such as a mono-cultural crop field.

Monocyclic Pathogens:-

This type of pathogens have the common features:

- one generation of inoculum per season
- primary inoculum only
- often soilborne pathogens

-no secondary cycle

Disease severity is directly dependent on-

the level of the initial inoculum and the efficiency of primary infection

Polycyclic Pathogens:-

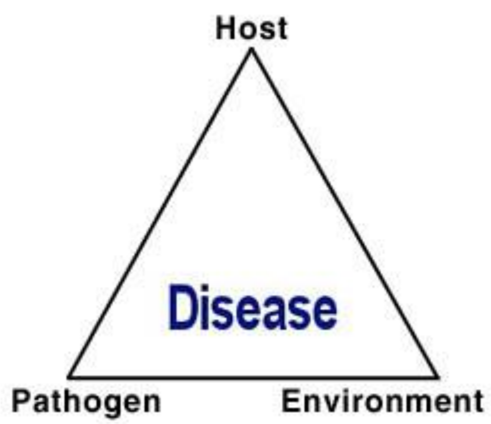
This type of pathogens have the common features:
-several generations of inoculum per year
-primary and secondary inoculum produced
-often airborne or vectorborne

-have a secondary cycle

Disease severity is primarily determined by –

rate of pathogen reproduction, and-spread of the pathogen. Initial inoculum is also a determining factor, but not as important as in the monocyclic pathogens.

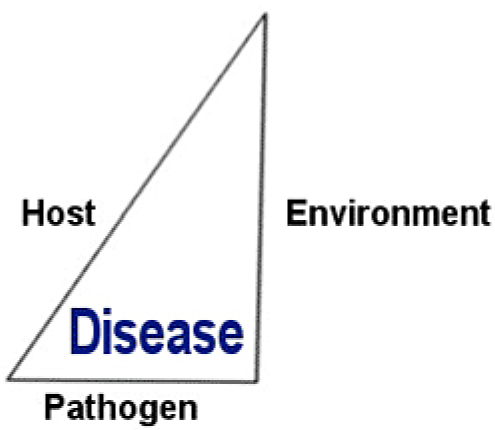
DISEASE TRIANGLE



This triangular relationship is unique to phytopathology in comparison to veterinary and medical sciences because terrestrial plants possess little thermal storage capacity and their immobility precludes escape from an inhospitable environment. The sophisticated immune system found in mammals is absent in plants, and this places an emphasis on the host's genetic constitution. Finally, the predominance in phytopathology of fungi, which are also highly dependent on environment, may have contributed to the development of this paradigm.

The disease triangle drawing most likely was first published by Stevens in 1960, although earlier plant pathologists certainly recognized the interaction among plant, pathogen, and environment. The abundance of a very large number of fungus diseases is directly connected with or conditioned by climatological factors; factors may affect independently host and parasite, and they may affect the interrelations of these organisms.

In a qualitative sense, the disease triangle concisely illustrates the phenomenon of plant disease as occupying the interior space of a triangle with the three essential factors at the vertices (Figure 1). Alternatively, the three factors may be associated with the line segments (i.e., triangle sides); then, line length and interior volume can show variation in the strength of the relationship in a quantitative sense (Figure 2). For example, a host with some degree of resistance, but not immune, will result in an overall lower level of disease. Used in this sense, the disease triangle illustrates the continuum of host reaction from complete susceptibility to immunity. So too, the degree of pathogen virulence and environmental conduciveness may be conveyed equally well. If any one element is reduced to a null variable, the geometric figure transforms into a line and the area occupied by disease collapses to zero. Aside from this null case, the alternative quantitative representation (Figure 2) treats disease as a degree of intensity (i.e., incidence or severity) rather than as a phenomenon.



DISEASE PYRAMID

Traditionally speaking the disease triangle is most often comprised of three factors: host, organism, environment. However, in some less traditional settings a fourth factor (time) is included in a four-dimensional figure to show the impact of time in addition to the host, organism, and environment. A period of time is normally required between when a host comes in contact with a pathogen and a favorable environment for disease to develop occurs.
More specifically, each of the factors are outlined below:

1. The host:
In our production system, regardless of planted crop (whether corn, cotton, grain sorghum, rice, soybean, wheat) more often than not, but not in every field situation, a susceptible cultivar is planted that does not contain resistantance genes for a particular disease. However, for some foliar diseases, specifically in corn and soybean, there are

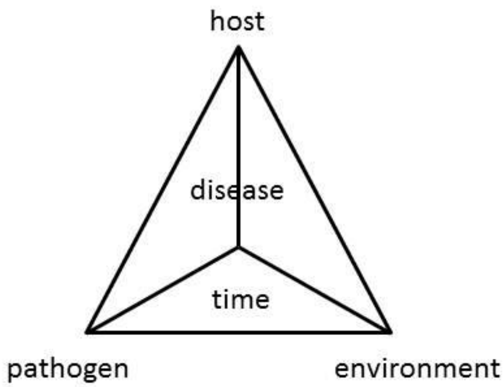
plenty of varieties available with some level of tolerance to a particular pathogen/disease (e.g., frogeye leaf spot).

2. The pathogen:

The pathogen is simply any particular organism (bacterial, fungal, or viral), but in this particular situation refers to the fungal organisms, that can cause a disease in a particular crop plant. In some cases the pathogen is present at a particular location especially if a continuous crop has been grown. Most fungal organisms can overwinter in a field between seasons on senesced plant material or even in the soil profile. The fact that fungi can overwinter within a particular field is one major reason that rotation as well as planting a resistant variety is such an important consideration.

3. The environment:

The environment is probably the single most delimiting factor for the development of a plant disease situation. Hence the side of the disease triangle for the environmental factor being skewed. Without a conducive environment, a plant disease will not occur. In most cases, a conducive environment involves high humidity, or free moisture• on the leaf surface in the form of dew as well as moderate temperatures. Most fungi do not like the temperature extremes. However, the environment must remain conducive for a specific amount of time for disease to occur. Time is the key component lacking in the three-dimensional disease triangle and the reason for the additional fourth component since a prolonged period of exposure between the host and the pathogen in a conducive environment will be required prior to disease incidence and symptom expression.



The four-dimensional disease pyramid with “time” added.

4. Time

Disease does not occur instantaneously, even in situations where a conducive environment remains present for an extended period of time. Time is required for the pathogen to infect the plant and produce characteristic lesions as well as produce sporulation (the asexual phase of reproduction). A prolonged period of time can also elapse between infection of the plant and symptom expression. Specific diseases where this likely tends to occur include *Cercospora* leaf blight and soybean rust.

In addition, in certain disease situations an extended period of time may be required for infection, disease development, and continued sporulation to occur. As I said above, disease incidence is not instantaneous. Several days may be required to go through several stages of reproduction.

Plant disease forecasting

Plant disease forecasting is a management system used to predict the occurrence or change in severity of plant diseases. At the field scale, these systems are used by growers to make economic decisions about disease treatments for control. Often the systems ask the grower a series of questions about the susceptibility of the host crop, and incorporate current and forecast weather conditions to make a recommendation. Typically a recommendation is made about whether disease treatment is necessary or not. Usually treatment is a pesticide application.

Forecasting systems are based on assumptions about the pathogen's interactions with the host and environment, the disease triangle. The objective is to accurately predict when the three factors – host, environment, and pathogen – all interact in such a fashion that disease can occur and cause economic losses.

In most cases the host can be suitably defined as resistant or susceptible, and the presence of the pathogen may often be reasonably ascertained based on previous cropping history or perhaps survey data. The environment is usually the factor that controls whether disease develops or not. Environmental conditions may determine the presence of the pathogen in a particular season through their effects on processes such as overwintering. Environmental conditions also affect the ability of the pathogen to cause disease, e.g. a minimum leaf wetness duration is required for grey leaf spot of corn to occur. In these cases a disease forecasting system attempts to define when the environment will be conducive to disease development.

Good disease forecasting systems must be reliable, simple, cost-effective and applicable to many diseases. As such they are normally only designed for diseases that are irregular enough to warrant a prediction system, rather than diseases that occur every year for which regular treatment should be employed. Forecasting systems can only be designed if there is also an understanding on the actual disease triangle parameters.

Plant disease forecasting models must be thoroughly tested and validated after being developed. Interest has arisen lately in model validation through the quantification of the economic costs of false positives and false negatives, where disease prevention measures may be used when unnecessary or not applied when needed respectively. The costs of these two types of errors need to be weighed carefully before deciding to use a disease forecasting system.

Information’s needed for disease forecasting Forecasting diseases is a part of applied epidemiology. Hence, knowledge of epidemiology (development of disease under the influence of factors associated with the host, pathogen) is necessary for accurate forecasting. The factors of epidemic and its components should be known in advance before forecasting is done. The informations required for forecasting are:

1. Host Factors

a. Prevalence of susceptible varieties in the given locality b. Response of host at different stages of the growth to the activity of pathogen e.g. Some diseases are found during seedling stages while others attack grown up plants and c. Density and distribution of the host in a given locality. Dense populations of susceptible variety invite quick spread of an epidemic. Growing susceptible varieties in scattered locations and that too in a limited area are less prone to epiphytotic.

2. Pathogen factors

a. Amount of primary (initial) inoculum in the air, soil or planting material b. Dispersal of inoculum c. Spore germination d. Infection e. Incubation period f. Sporulation on the infected host g. Re-dispersal / Dissemination of spores h. Perennating stages i. Inoculum potential and density in the seed, soil and air

3. Environmental factors

a. Temperature b. Humidity c. Light intensity d. Wind velocity Requirements or conditions for disease forecasting

There are five main requirements which must be satisfied before a useful and successful disease forecast is made.

1. The disease must cause economically significant damage in terms of yield loss or quality. Damage assessment is essential to develop strategy for controlling a disease. e.g., Annual estimation of yield loss caused by barley powdery mildew (*Erysiphe polygoni*) in England and Wales had ranged from 6 to 13 %. Potato late blight can cause a yield loss of 28% if the disease reaches the 75% stage by mid- August. Diseases like apple scab and potato common scab reduces the quality of the produce lower the value of the harvested crop and cause considerable financial loss to the growers.

2. Control measures must be available at an economically acceptable cost.

3. The disease must vary each season in the timing of the first infections and its subsequent rate of progress. If it does not, there is no need for forecasting.

4. The criteria or model used in making a prediction must be based on sound investigational work carried out in the laboratory and in the field and tested over a number of years to establish its accuracy and applicability in all the locations where its use is envisaged.

5. Growers must have sufficient man power and equipments to apply control measures when disease warning is given. Long-term warnings or predictions are more useful than short-term warning or predictions.

Methods of disease forecasting Disease forecasting requires field observations on the pathogen characters, collection of weather data, variety of the crop and certain investigations and their correlations.

Usually the following methods are employed in disease forecasting.

1. Forecasting based on primary inoculums

2. Forecasting based on weather conditions

3. Forecasting based on correlative information Weather data of several years are collected and correlated with the intensity of the diseases.

4. Use of computer for disease forecasting

Relevance in Indian context

Four major approaches of disease management in the Indian context are outlined and the most appropriate one is considered to be host resistance. Adoption of this approach has yielded promising results for five major disease groups. It is pointed out that, so far, among the materials released which are resistant to one disease, or one set of diseases, most turn out to be susceptible to another set of diseases. The development of multiple resistance to the major diseases prevalent in the diverse agro-ecosystems of India seems more appropriate. The population improvement approach through a recurrent selection scheme was adopted and since 1973, a high level of resistance to as many as 12 diseases has been developed (in case of maize disease). Although seven disease groups are amenable to chemical control, a very favourable cost: benefit ratio (1 : 14) is obtained only for seed and seedling groups of disease. Certain agronomic practices also help in reducing incidence of certain disease groups. The total estimate of loss in economic product per annum due to all diseases taken together has been estimated to be 13.2%.