Epidemiology

In this chapter, we draw together the interactions which lead to progress of disease (epidemic) in a population. NOTE that we are being careful to indicate that diseases progress, which is to say that the parasitic relationship of hosts AND parasites are both necessary for disease. We do not say that the disease spreads because that would indicate that the disease could be propagated when in fact it possesses no means for propagation. The exception to this is, when after infection, a pathogen causes disease within a plant and in the growth (ramification) of the parasite the disease apparently "spreads". If; however, reinfection of the host is required for continued progress of the disease then the "spreading" of the disease has ceased.}

As with any discipline or sub-discipline, epidemiology has a "language" or "expressions" which it uses to communicate.

Thus, the first step is to describe **some of the expressions.**

Epidemic: The progress of a disease in a population.

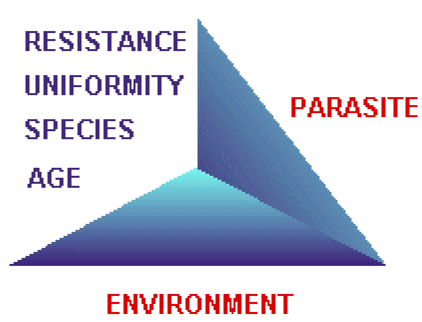
Epidemiology: The science of disease in populations. (This is NOT synonymous with the study of Pathogen populations.)

r (or $\mathbf{r}_l$): This denotes the ***infection rate*** and is largely what epidemiology is about. In a the single value, **r**, an epidemic can be described. **r** is expressed as **X per Unit per Time Period.** To use Van der Plank's analogy of increasing human population; if, over a 10 year period, a human population increased 250 (persons) per 10,000 (persons) per year. One would conclude that the average rate of increase was 2.50%, or the average rate was 0.025 per unit (person) per year (time). Under these conditions **r = .025**. This is at least double the population increase in the U.S. but is given to enable one to get a "feel" for an r value.

In 1953, Late Blight of Potatoes increased in a field of potatoes in the Netherlands at a rate of r =.42 per unit per day. This r value indicates that the parasite/pathogen (*Phytophthora infestans*) is virulent, the host (potato) is susceptible and the environment is not limiting to the disease. If, in the same field, another variety of potato the r =.11 then one could conclude that this variety possessed some resistance to *Phytophthora* because the environment and pathogens were the same but the host was different.

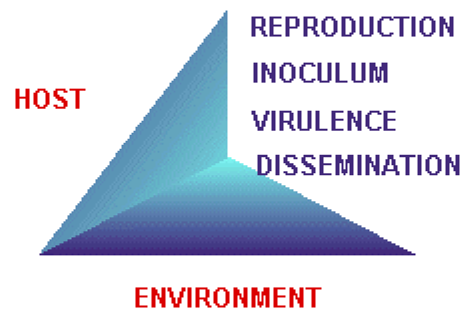
The Elements of an Epidemic

Agrios uses the Disease Triangle/Tetrahedron to introduce the factors necessary for an epidemic; namely, Host, Parasite, Environment, Time. The disease triangle is a conceptual device to reinforce one's intuitive understanding that disease occurrence is dependent on a susceptible host, a virulence pathogen and a conducive environment. Remember that disease is the entirety of the phenomenon not just the initial phase. Pathogenesis must follow infection in order for disease to occur. The effect of environment is as important to the disease progress as it is to infection. A significant factor not presented by the disease triangle is TIME. A situation may occur where the host, parasite and environment factors occur; but if they don't occur at the right time then disease will not result. Diseases are often managed through the use of time, i.e. time of planting, time of harvest, timing of varieties, rotations, etc. With respect to epidemiology, time (rate) is the central concept.



Host Factors that Affect Development of Epidemics

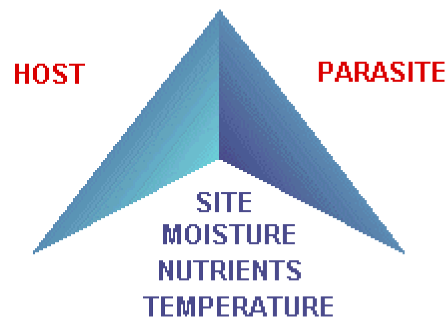
- Levels of Genetic Resistance or Susceptibility of the Host: Plants vary in their genetic resistance to infection and/or pathogenesis by specific organisms. Even within a species, varieties can be, and are, selected for their resistance to specific pathogens.



- Degree of Genetic Uniformity of Host Plants: Monoculture of crop species is the most common agronomic and horticultural (turf) practice. This is convenient and allows producers to better manage their time and resources. However, monoculture places a high degree of selection pressure on parasites and when resistance fails it is likely to lead to very large losses because the, formerly resistant, monoculture has become a susceptible monoculture.
- Type of Crop: The generation time of the crop; annual, perennial plays a role in disease progress. Often one is concerned about epidemics in annual crops because they appear dramatically and if not controlled lead to destructive losses. The same dynamics of disease progress occur in perennial species when viewed with respect to their generation time. Fruit and forest species may have slower progressing diseases on a chronological basis and at the same time may be progressing more rapidly relative to the life span of the host.
- Age of Host Plants: Some plants are more susceptible as juveniles while others are more susceptible as adults. Though the observation may be consistent, one must be careful not to disregard the changing environment during a plant's life.

Pathogen Factors that Affect Development of Epidemics

- Levels of Virulence: Virulence is a pseudo-quantitative value to express the ability to cause disease. This term is equivalent to the term resistance respective to hosts. A parasite that has very low virulence may be able to exist on a host in a parasitic relationship but will be unable to become a pathogen. Virulence levels are often determined with respect to host resistance levels and as such virulence has become linked in concept with the ability of a parasite to thwart host resistance.



- Quantity of Inoculum Near Hosts; proximity is the key. Irrespective of the amount of inoculum available, if its not near a host it can't be a factor.

- Type of Reproduction of the Pathogen/ Ecology of the Pathogen: Some fungi reproduce only asexually. Others reproduce sexually. While others require mating types for sexual reproduction. Some parasites require free water, while others are inhibited by free water. Therefore, one must know the biology of the parasite in order to understand the potential for disease and be able to predict disease progress.
- Mode of Spread of the Pathogen: With the exception of nematodes and zoospores, all plant pathogens are dependent of external forces; i.e. wind, water, insects, humans, soil ,etc, for their dissemination. Some are very specific in their needs for a vector while others are effectively disseminated as transients.

Environmental Factors that Affect the Development of Epidemics

- Moisture: Because the infective propagule of most plant pathogens is a single cell with little to protect it from dessication, moisture in the form of humidity, is important to the survival of the inoculum. For dissemination, some parasites require free water and others are favored by wind driven rains. The effect of moisture on the host should also be considered because of its effect on plant vigor. Low moisture may lead to wilting and collapse, while excessive moisture can lead to anoxia in roots thereby weakening the plant and increasing vulnerability to pathogenic activity.

- Temperature: Temperature maybe the poorest understood factor in disease. It has been assumed that temperature has a *grow or no grow* effect on plants and as such outside of these general parameters has little to do with disease progress. However, recently experiments have shown that the effects of temperature are dramatic and persistent. Temperatures that inhibit host may not effect the parasite and *vice verse*. There is every reason to believe that daily temperature cycles play a modulatory role in plant disease progress.
- Nutrients: There is a direct relationship between plant nutrition and disease progress. Unthrifty plants due to poor nutrition have increased susceptibility. Plants that are grown under nutrient conditions, such as high nitrogen, may also have increased disease susceptibility.
- Site: Where a plant is grown and the environment (temperature, humidity, air flow, etc) are very large factors in whether disease will occur. Often our crop species are grown far away from and under very different conditions than were their progenitor species; corn, potatoes, tomatoes, horticultural species, etc.

Effect of Human Cultural Practices and Control Measures

- Site Selection and Preparation
- Selection of Propagative Material
- Cultural Practices
- Disease Control Measures
- Introduction of New Pathogens

Measurement of Disease

Epidemiologists use specific terminology to accurately communicate magnitudes and potentials for disease

- Incidence: the number or proportion of plant units diseased
- Severity; the proportion of area or amount of plant tissue that is diseased
- Yield loss; the proportion of yield that a grower will not be able to harvest due directly to the disease
- Economic loss; the reduction in economic returns due to disease. What about compensation of plants which results in no yield loss though one has up to 50% plants lost due to disease? Think about the "Green Revolution".
- Economic threshold; when the amount of gain from control equals the amount of estimated loss from the disease.)

The Structure of Epidemics

- An epidemic is a biological process. As such it will progress in an orderly and predictable fashion. Because ALL biological entities, you and me included, are either increasing or decreasing, growing or waning, learning or veg-ing; one should ALWAYS expect that the data will be expressed in some sigmoid or logarithmic curve. NEVER expect data concerning living things to be linear. If they are, then treat the data as suspect.

Patterns of Epidemics

- "If rain makes the pathogen multiply faster, rain increases the infection rate. A more susceptible host, a more aggressive pathogen, and weather more favorable to disease all increase the rate. Every factor that affects the rate of increase of disease affects the logarithmic and apparent infection rates. Irrespective of whether the factor is contributed by host, pathogen, or environment. Every contribution, whatever its source, is pooled in the one single comprehensive figure that estimates the rate". Van Der Plank, Plant Diseases: Epidemics and Control.

Epidemiology Terminology Continued -- Disease-progress curve

- p = latent period (generation time i.e. from spore to spore)
- R = basic infection rate; $dx_t/dt = rx_t(1-x_t)$
- x_t = proportion of infected tissue
- t = time
- d = change over unit time (t)
- r = Apparent infection rate
- x_o = Incubation period (time from infection to disease)

Monocyclic diseases Monocyclic diseases by definition are diseases in which the pathogens complete only one generation, or part of a generation, in a given year and thus reinfection due to a new generation of pathogen does not occur during a single year. The emphasis is on the completion of the disease cycle and not completion of all reproductive stages of the pathogen. Corn smut caused by *Ustilago maydis*, for example, produces its teliospores at the end of the season. These spores overwinter in or on soil, germinate producing basidia and basidiospores which infect the host. It takes a full year for completion of the disease cycle, thus the application of the term monocyclic to this disease.

- **Simple Interest Diseases**: Infection occurs but reinfection from the resultant propagules does not occur during either the growing season. Thus if 10% of plants become infected initially, the incidence of disease will be 10% of the plant population. The consideration is that the amount of disease on each infected plant can be quite variable; therefore two varieties may have the same degree of exposure and may even be equally infected but the amount of disease can vary considerably.

With regard to Corn Smut, it is a Monocyclic and Simple Interest Disease, because it does not it does not spread in a given year by virtue of production of new propagules. It therefore, satisfies the definition very strictly.

The concept of Simple Interest Diseases is most often applied to annual crops and some of their diseases, when the crop is rotated with a crop that is not infected by the disease encitant. Vascular wilts caused by *Fusarium* sp. are characteristic. Plants become infected and disease may ensue but the propagules produced (asexual conidia, chlamydospores, and mycelia) remain in the infected plant. Vascular parasite while defined as Simple Interest Disease may also be considered as polycyclic. They certainly produce large quantities on new infectious inoculum during the crop's growing season but are limited to being Simple Interest Disease because the inoculum is retained inside the diseased plant. Inoculum may increase over time (seasons) if the susceptible host is replanted, thus the appropriate disease management strategy is crop rotation.

- **Log_e[1/(1-x)]** : This term expresses the progress of a Simple Interest Disease. This term presumes that tissue that is diseased cannot be infected and uses the correction factor (1-x) to indicate that the amount of susceptible tissue has been reduced.

  The use of the Log_e term recognizes that biological entities, in this case the pathodeme, increase in a geometric fashion not arithmetic.

Stalk Rot of Corn

is exacerbated by the presence of *Fusarium moniliforme* and *Fusarium graminearum* as vascular parasites. Corn is planted into soil infested with *Fusarium* propagules. As the seed germinates it's radicle and young roots come in contact with the germinating spores or a growing mycelium of the facultative parasite *Fusarium*. Taking advantage of micro-wounds, the *Fusarium* infects the plant ramifies intercellularly until it reaches the vascular tissue. Once it reaches the vascular tissue, it sporulates and the spores are carried up the plant in the phloem stream. *Fusarium* is a "good" parasite and seldom kills the corn plant except possibly after a severe environmental event (drought, heat, etc.). The mycelium and spores remain in the plants though out the season and are returned to the soil as the crop is harvested and the plant debris is incorporated back into the soil.

In the great plains of the U.S. corn is grown to a large extent as a monoculture and without rotation. Consequently, overtime the inoculum has reached a biological equilibrium with the ecosystem and is both ubiquitous and stable. Therefore, it can be considered as a simple interest disease. Because of the large acreages planted and the lack of rotation it is unlikely that one can expect any reduction in this disease without a major effort to improve the genetic resistance of the host. With the advent of hybrid corn, great strides have been made to make corn more resistant to lodging (stalk collapse resulting in the plant's falling over) but little or no improvement in the genetic resistance of corn the *Fusarium* has been demonstrated.

Overwintering inoculum in Simple Interest Diseases - The amount of potential new inoculum produced by a pathogen in a Simple Interest Disease can be quite substantial. It is, therefore, important to consider the ability of the pathogen, in it's various forms, to successfully overwinter until the next season. Some pathogens do not survive well when exposed during the "off-season" while others do not survive being incorporated into the soil. It either case it is important, from a disease control perspective to know the biology of both host and parasite in order to predict disease potential.