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Concepts of Epidemiology

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Epidemiology has been conceived in various ways. For some, it is the study of factors affecting the outbreak and spread of infectious diseases; for others it is the dynamics of diseases in host populations, and for still others it is, more narrowly, disease dispersal and spread, within all these concepts, comparison is possible and justifiable. Epidemiology consists of a complex set of concepts, definitions, and analytic procedures. Vanderplank has defined it as "the science of the disease in populations". The important populations are those of the host and pathogen. Epidemiology is also concerned with host-pathogen interactions that lead to disease and crop losses. These interactions are often environmentally dependent, so epidemiology deals with effects of the biotic and abiotic environmental factors. Finally, man has had important effects on hosts, pathogens, and their environments. So epidemiology also deals with the influence of man on disease. Campbell and Madden (1990) defined plant disease epidemiology as the "study of the temporal and spatial changes that occur during epidemics of plant diseases that are caused by populations of pathogens in populations of plants". All of this can be symbolized by the disease tetrahedron (Fig. 1).

Epidemiology in its practical sense is the study of disease mounting to a level of economic thresholds. Comparative epidemiology attempts to enlarge our comprehension of complex pathosystems beyond simple description of similarities and differences within and amongst epidemics and their constituents, or comparison of experimental treatments. Plant disease epidemiologists strive for an understanding of the cause and effects of disease and development 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.

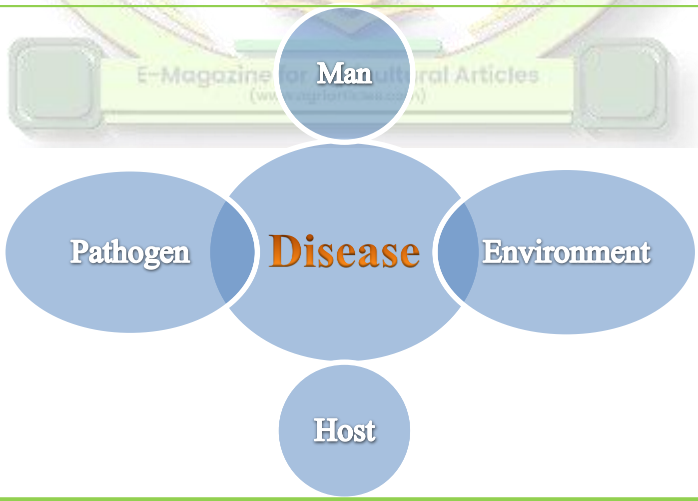

Fig. - 1: The disease tetrahedron

These four elements mutually influence each other but the various influences are not equally strong at all levels of integration.

Positioning of Epidemiology

Epidemiology is at the cross roads of principles oriented science, ecology and problem oriented but multileveled science phytopathology (Fig. 2).

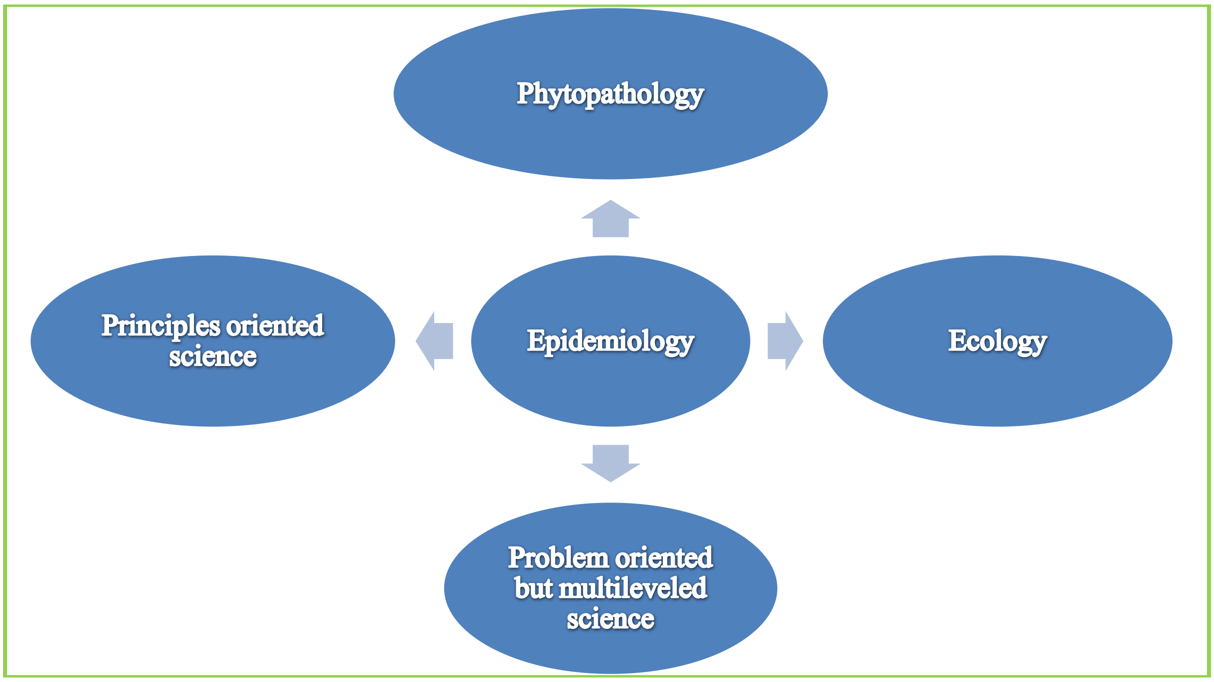

Fig. 2: Position of epidemiology

Branches of Epidemiology

- **Descriptive epidemiology:** It describes the epidemics and factors that seem to affect it.
- **Quntitative epidemiology:** Quantifies or measures various metrics of an epidemic.
- **Comparative epidemiology:** Compares different pathosystems in different ecosystems, or even different pathosystems. Most comparative epidemiological studies are also quantitative. Comparison of different cropping regimens leads to comparative epidemiology.

Some Basic Concepts of Epidemiology

In one sense, epidemiology can be viewed as a logical extension of etiology (the study of how the pathogen causes disease, its life cycle and how the host plants react). After studying the pathogen's life cycle and its relationship to the host plant with regards to how it causes disease, the interest shits to studying how the pathogen survives and causes disease on subsequent generations of plants. By describing the relationship between populations of pathogens and populations of plants then comes descriptive epidemiology. Given the proper tools to measure epidemics and condense the large amount of data, we begin to quantity epidemics (quantitative epidemics). Finally, if we want to study how we might affect the course of an epidemic by changing the different components of agro-ecosystems, we need to be able to compare the epidemics in the different systems, and thus we enter the field of comparative epidemiology. Exactly where we lie on this continuum is in part a reflection of how much we know about the disease, and the economical importance of the disease and of the crop. For many diseases, we are in the comparative and quantitative stages, but for many lesser known plant diseases, much of the etiology and descriptive epidemiology remains.

Epidemiology and Related other Sciences

Because of its broad purview, epidemiology must draw upon many sciences, and epidemiologists must have knowledge of these.

Life sciences - 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.

Physical sciences - Physics and mathematics, environmental physics is of paramount importance, especially meteorology and micrometeorology. In mathematics, calculus, statistics, and computer science contribute most directly to epidemiology. 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.

Epidemiology as a biologic specialty, devoted to research and in its basic research it tries to identify the principles governing epidemic processes. Whereas, in its application research, it directs its attention to the solution of problems that appear in agricultural practice. The results of good epidemiologic research lead to recommendations for crop protection and if such recommendations are to be truly useful, they must fit into an appropriate general disease management scheme. So epidemiology and disease management are, like two sides of a coin.

The uses of Epidemiology

The study of epidemiology serves at least two purposes. It has a scientific as well as a practical role. Both are useful, the first leads to understanding of the behavior of disease in time and space and the second using that understanding to manage disease.

Plant disease is controlled by various means *viz;* pathogen avoidance, pathogen exclusion, pathogen eradication, protection, host plant resistance and disease therapy. The determination of which ones to use for specific disease(s) depends on epidemiology of that particular disease or diseases. The choice of which combinations can be used for continued management of single disease or for several diseases of sequential crops on the same field requires the knowledge of epidemiology. So, Vanderplank (1963) quoted "Chemical industries and plant breeders forge fine tactical weapons but only epidemiology sets the strategies".

Ecologically plant diseases are part of nature. They cannot be banished, nor there is need to do so. They must be lived at times with uncomfortable compromise. That is the main idea of disease management. Epidemiology provides the bases for evaluating control need, control efficacy, and control stability. In brief one can say that for epidemiology to remain a consistent and applicable body of knowledge it must limit itself to the study of pathosystem at three integration levels.

Table 1: Three integration levels of epidemiology

Size	Components	Time scale	Example
Those of the individuals	Organs	Many weeks	Potato plant
The population	Many individuals	Months	Wheat field
The community	Several populations	Long years	Wood and forest

These are studied and are called as monocyclic, polycyclic, and polyetic processes respectively.

Some epidemics man has known

Period	Epidemic	Area
10^{th}-19th cent.	Ergot of rye (*Claviceps purpurea*)	Europe
1780-	Fire blight of pear etc. (*Erwinia amylovora*)	USA, 1780- & UK, 1957-
1791-	Peach yellows (Peach yellows virus)	Eastern USA
1845-	Potato blight (*Phytophthora infestans*)	Ireland
1869-	Coffee rust (*Hemileia vastatrix*)	Sri Lanka
1878-85	Vine mildew (*Plasmopara viticola*)	France
1880-1950	Panama disease of banana(*Fusarium oxysporum* f.sp. *cubense*)	C. & S. America
1904-	Chestnut blight (*Cryphonectria parasitica*)	Eastern USA
1920-70	Dutch elm disease (*Ceratocystis ulmi*)	Netherlands, USA & UK
1942	Rice brown leaf spot (*Cochliobolus miyabeanus*) The Great Bengal Famine	India (Bengal)
1970	Maize leaf blight (*Helminthosporium maydis*)	Southern USA
1970s	Leaf rust (*Puccinia recondita*)	Northern India
1970s	Karnal bunt (*Tilletia indica*)	Northern India

Since then time to time epidemics of many diseases occur in different parts of the world though the magnitude and extent of such epidemics are not as damaging as it used to be.

Impact of Plant Disease Epidemics on Human Culture

Ergot of rye: The defeat of Peter the great of Russia in his fight to gain control of certain warm-water ports on the Black Sea in 1972 was due to the ergotism. Ergotism was due to the ergot of rye caused by *Claviceps purpurea*. This fungus invading the grain produces an ergot that contains many alkaloids including a hallucinogenic drug, LSD. When grains with ergot are ground and baked to bread, the problem begins.

Small amounts of alkaloids can induce abortion in cattle and in man. Larger amounts can cause can fingers and toes to tingle, and high fever that can result to derangement and even death if the fever persists. The patient may also experience hallucinations and even gangrene of the extremities after ingesting contaminated rye bread.

Sacer ignis-the holy fire was also an epidemic of ergotism during the 857 AD in the Rhine Valley in Europe killing thousands of people. The monks of St. Anthony were able to relieve the symptoms of the disease in 1039 AD in France and the disease was known as St. Anthony's fire. The monks fed the patients with ergot-free bread together with spiritual administrations. An epidemic of ergot of rye has also lead to the accusations of witchcraft in Salem Village, Massachusetts and in Fairfield Country, Connecticut in 1962 as shown by some evidences. In 1951, weather conditions have allowed ergot to develop in rye in France.

Coffee rust: Arabs brought coffee from Ethiopia about AD 1000. From Arab it was introduced to south India and from India coffee was taken to Ceylon (Srilanka), where it was well adapted. The British in Ceylon, now Sri Lanka, who were coffee drinkers, became a nation of tea drinkers when *Hemileia vastatrix*, the causal agent of the devastating coffee rust came to existence. By 1870, two lakh ha of coffee were planted by the British in Ceylon with 50 million kg of coffee beans for export per year. A year ago, M.J. Berkeley was able to describe and name *Hemileia vastatrix*, the disease results to the premature falling of leaves in about a hectare of land and suggested that sulfur be immediately applied to prevent further spread of the fungi. No one took heed on Berkeley's suggestions and by 1874; the disease has ecome widespread on the island and has reduced 55% of the total yield four years after. In 1880, Henry Marshall Ward arrived in Ceylon and studied the fungi, Hemileia vastatrix, and showed an effective way of controlling the disease but due to the high costs of the control method, farmers started to plant tea bushes. Tea became popular in Britain with the demise of coffee in Ceylon. Coffee rust also destroyed coffee plantations all over Southeast Asia and India and destroyed the whole continent's coffee industry in ten years. The disease has now introduced to Brazil and Columbia where it is spreading.

Peach Yellows: Peach yellows is a dramatic disease. Being a luxury crop, it did not induce starvation among the citizens but it seriously affected peach growers. Disease first broke out in Philadelphia about 1781 (Smith 1888) and by 1870 the disease had spread eastern to central Jersey, by 1814 to long Island and by 1820 to Connecticut.

Chestnut blight: The destruction of chestnut trees in the Americas was caused by *Cryphonectria parasitica*, formerly known as *Endothia parasitica* responsible for the chestnut blight epidemic that has caused a major effect in their industries. Chestnut was a major forest species in the United States contributing 25 per cent of the 100 commercial hardwood species in the southern Appalachian region. The nuts were good sources of food for humans and wild life while the wood was used in furniture, home and fences, as firewood, as decay-resistant poles, and as railroad tiles. The highly successful leather tanning industry was also a product of chestnut since chestnut was the major source tannin during that time.

In 1904, H.W. Merkel observed that the chestnut trees in the Bronx Zoological Park in New York City were dying caused by an exotic fungus, then *Endothia parasitica*. The fungus was brought to the United States and by 1911, the blight had spread over New Jersey and parts of New York, Connecticut, Massachusetts, Rhode Island, Delaware, Virginia and West Virginia and the pathogen continued to spread. As a result, entire communities of the Appalachians turned to other enterprises since their major source of tannin has disappeared.

Impact of Wars on Plant Disease Epidemics

Late blight of potatoes and World War I: Carefoot and Sprott (1967) describe how late blight of potatoes helped the British in defeating the Germans in World War I. Bordeaux mixture, (a mixture of copper sulphate and lime) that holy water of plant pathology, was discovered in France in 1882 was needed to save the potato from late blight disease and people who depended on the potato from starvation. But due to the war needs, military leaders did not release the copper since potato and grains were supplied for the army in 1916 and 1917. Military collapse of Germany in 1918 was due to the decline of morale of the army because although they were not hungry but their family were starving. So, morally soldiers were weakened.

The Great Bengal Famine: Almost 100 years after potato famine that killed an estimated 1.5 million Irishman, another famine struck in Bengal and killed an estimated 2 million of its citizens (Padmanabhan, 1973). Unlike Irish famine it was exacerbated by war; otherwise the two situations were astonishingly alike. Like Ireland, Bengal was overpopulated and was dependent on single crop- rice in this case. The Bengal weather in 1942, like that in Ireland in 1845 and 1846 was usually rainy and unusually cloudy. *Helminthosporium oryzae* struck and the rice was destroyed. The rains were a little too late for the fungus to kill off the early maturing varieties. Their yield was reduced by only 50 per cent. The disease hit the late maturing varieties harder and reduced their yields by 75 to 90 per cent. Fortunately for Bengalese, and in contrast to the helpless Irish, weather did not favour H. oryzae, in the subsequent years so their sufferings were limited mainly to 1943. The World War II worsened the famine because the Japans army had occupied neighbouring Burma (now Myanmar) and thereby shut off the normal flow of rice from the important source. British could not supply enough rice from elsewhere. Thus, there was a complex relation between plant epidemics and war.

Man Encourages his own Plant Disease Epidemics

Barberry/ wheat rust: Barberry (*Berberis vulgaris*), is the alternate host of *Puccinia graminis tritici*. In Roman times, traders carried wheat by ship through Mediterranean Sea to northern and western Europe, but did not take barberry so wheat flourished there for centuries, free of rust. However, somehow barberry bush was introduced in Italy and rust for the first time began to destroy European wheat. European farmers discovered the connection between barberry and wheat rust by 1660. However, even after establishing this relationship English colonists who moved to the United States in early part of that century brought barberries to New England and lost the chance of keeping wheat free from rust. So man had encouraged his own epidemic.

Southern corn leaf blight: A classical example of this is the epidemic of southern corn leaf blight, was due to the ignorance of man, in the United States in 1970. Epidemic of leaf blight hit throughout the corn producing areas of the eastern United States in the summer of 1970. February of the same year, the southern corn leaf blight, caused by *Bipolaris maydis*, was found in hybrids that have exhibited previous resistance. This was alarming since 85 per cent of the total corn planted acreage the US were planted with this hybrid. Hypersusceptibility to *Bipolaris maydis* by the hybrids was attributed to the use of the Texas cytoplasmic male sterility technique in producing the hybrids. The hypersusceptibility of Toms hybrid was first discovered in the Philippines by Mercado and Lantican in 1961. In 1969, Race T, a new race, of *B. maydis* invaded the Corn Belt. Race T was highly virulent on corn with Toms but mild on corns with normal cytoplasm.

By May 1970, Southern corn leaf blight has invaded the southern United States and was moving northward due to weather conditions by June. Since 85% of the corn planted was susceptible, losses ranged from 10-30% resulting to 15 per cent of the U.S. corn crop or about 20 million metric tons of corn (about $1 billion) was lost.

Conclusion

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.

References

1. Van der Plank, J. E. (1963). Plant diseases. Elsevier Science.
2. Huber, L. and Gillespie, T. J. (1992). Modeling leaf wetness in relation to plant disease epidemiology. *Annual review of phytopathology*, **30**(1): 553-577.
3. Milgroom, M. G., & Peever, T. L. (2003). Population biology of plant pathogens: the synthesis of plant disease epidemiology and population genetics. *Plant disease*, **87**(6): 608-617.

4. Milgroom, M. G. and Fry, W. E. (1997). Contributions of population genetics to plant disease epidemiology and management. In *Advances in Botanical Research*. Academic Press, 24: 1-30.
5. Nelson, M. R., Orum, T. V., Jaime-Garcia, R. and Nadeem, A. (1999). Applications of geographic information systems and geostatistics in plant disease epidemiology and management. *Plant Disease*, **83**(4): 308-319.