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Review on the Contributions of Some Human Cultural Practices to Plant Disease Epidemiology

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Abstract
An epidemy of a disease usually occurs when there is an interaction of the three (3) major factors of disease development popularly called disease triangle. The disease triangle consists of a susceptible host, virulent pathogen, and a suitable environment that favors the growth of the pathogen. When the two other factors interact with the pathogen, disease can reach epidemic condition referred to as epiphytotic stage. However, apart from these factors, many activities of human have a direct or indirect effect on plant disease epidemics, some of them favors and some reducing the frequency and the rate of epidemics. It has been established that some on-farm cultural practices such as selection of planting site, tillage, continues mono cropping and monoculture, inter cropping, spacing between plants/ plant density, weeding, crop rotation, fertilizer application and many others when misused or used carelessly may tend to allow or favor the development of epidemy by creating a suitable environment optimum for pathogen growth and development and sometimes making the host plant vulnerable to some peculiar diseases. This when human cultural practices are considered appropriately together with the disease triangle, could change the triangle shaped factors to a tetrahedral structure necessary for disease development. In this paper, major on-farm cultural practices that contribute to the epidemy of disease and the need to incorporate these factors as the fourth item in the disease factors are discussed.

Keywords: epidemy, disease triangle, human cultural practices, tillage, fertilizer application, disease square

INTRODUCTION

In phytopathology, an unexpected outbreak of a plant disease within a relatively short period over a large area and affecting many agricultural fields is called epidemic or epiphytotic (Agrios, 2005). When a plant pathogen spreads to and affects many individual plants within a population over a relatively large area and within a relatively short time, the phenomenon

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is called an epidemic. An epidemic has been defined as any increase of disease in a population. A similar definition of an epidemic is the dynamics of change in plant disease in time and space. The study of epidemics and of the factors that influence them is called epidemiology (Agrios, 2005). Epidemiology is a branch of plant pathology which deals with the study of pathogen population in relation to host population and resulting disease under the environmental and human factors. Plant disease epidemiology has also been defined, according to Madden *et al*. (2007) as the study of various factors that affect the spread of disease in time and space.

Plant disease epidemics/ epiphytotics, occur annually on most crops in many parts of the world. Most epidemics are more or less localized and cause minor to moderate losses. Some epidemics are kept in check naturally, e.g., by changes in weather conditions. Others are kept in check by chemical sprays and other control measures. Occasionally, however, some epidemics appear suddenly, go out of control, and become extremely widespread or severe on a particular plant species. Some plant disease epidemics, e.g., wheat rusts, southern corn leaf blight and grape downy mildew, have caused tremendous losses of produce over rather large areas. Others, e.g., chestnut blight Dutch elm disease, and coffee rust, have threatened to eliminate certain plant species from entire continents. Still others have caused untold suffering to humans. The Irish potato famine of 1845–1846 was caused by the *Phytophthora* late blight epidemic of potato, and the Bengal famine of 1943 was caused by the *Cochliobolus* (Helminthosporium) brown spot epidemic of rice, ground nut rosette epidemy of 1985 in Nigeria, to mention a few.

In phytopathology, epidemy of most diseases are usually been perceived to be due to the three major factors of disease development, namely; pathogen, host and environment. In most cases the fourth major factor (human cultural practices) is seriously neglected or not even considered as a reason for an epidemy. But careful observation on human cultural activities shows that these cultural activities also contribute immensely in outbreak of disease and its epidemiology and could be considered as the fourth factor of disease development so that the disease triangle could even become a complete square. This is the basis of this review.

THE REQUISITES OF DISEASE DEVELOPMENT

The disease triangle

The development of any disease in plants community is greatly determined by three major elements namely; the host, the pathogen and the environment all of which could be depicted in the form of a disease triangle. Disease triangle therefore represents all the three conditions essentially required for disease to develop in any plant host community. It is the balance of the interaction of these requisite conditions that determines whether or not disease develops to destructive levels in a particular situation. For the development of epiphytotic, there is a need for a forth factor which is the human agricultural practices which are conducted either on-farm or during land preparation. The third factor earlier mentioned is the environment. The environment has the ability to influence the earlier two major factors which are the susceptibility of the host (e.g. by predisposing it to infection) and the virulent pathogen. The pathogen can affect the host and the host can influence the pathogen (e.g. by secreting chemical factors). An understanding of these factors and their interactions for a particular disease in a particular locality allows prediction of disease outbreaks popularly called disease forecasting and this can assist in reduction in the amount of disease (Agrios, 2005).

Therefore, an epidemic could develop only when few repeated generations are completed by the pathogen on the same host. As each generation or cycle of the pathogen takes a few days for completion, the fourth parameter i.e. time factor (forms a disease tetrahedron or disease pyramid) is also involved in epidemic build up (Van der Plank, 1983). In other words, epidemic growth is both temporal (pertaining to time) and a spatial (relating to space or area) process. The initial stages of an epidemic growth curve have a lag phase, when the incubation period is longer, inoculum load is weak and prevalent environmental conditions are unfavorable. Subsequently, when the conducive environmental condition prevails, the growth of the disease is rapid and the severity of the epidemic explodes like a time bomb. Later, severity declines either due to unfavorable weather or crop maturity or both.

HUMAN CULTURAL PRACTICES

Cultural practices such as tillage, weeding, fertilizer application, inter cropping, and crop rotation as well as other control measures reduce or eliminate the possibility of an epidemic. Sometimes, however, the same cultural practices carried out by the poor resource farmers, may lead to selection of virulent strains of the pathogen (Agrios, 2005) and also provide the pathogens with enabling environmental conditions which can results into epidemics especially when these cultural practices are used wrongly or misused. Some of these cultural practices include the following;

Effects of Site Selection and Preparation on Disease Epidemiology

Selection of planting site is usually the first task that a farmer faces while deciding on what to plant in a particular season. Different crops possess different site requirements (Mehrotra and Aggarwal, 2003). Examples; rice requires sandy loam or clay loam soils from areas that are marshy. Soil that is water logged can suite rice production. However, potato requires sandy loam aerated soil so that any black heavy soil may tend to become problematic to potato production, etc. Low-lying and poorly drained and aerated fields, especially if near other infected fields, tend to favor the appearance and development of epidemics. Several soil borne pathogens, such as *Fusarium oxysporum* (the cause of vascular wilts), *Gaeumannomyces graminis* (the cause of take-all of wheat), *Phytophthora cinnamomi* (the cause of root rots of many fruit and forest trees), *Pythium* spp. (a cause of damping-off), and *Heterodera avenae* (the oat cyst nematode), develop well and cause severe diseases in some soils known as conducive soils, whereas they develop much less and cause much milder or even low severe diseases in other soils known as suppressive soils. Nematode and most wilt causing pathogens loves dark heavy and acidic soils (Kutama *et al.*, 2013a). Rice blast caused by *Magneporthe oryzea* is having a high incidence when rice is grown in upland soils. According to Joa˜o and Nunes (2011) upland environments are most affected by the disease where there is a large production of dew on the leaf surface, which favors the development of the pathogen. The water layer, in irrigated environments, serves as a thermal barrier that prevents heat loss from the soil, during the night, restricting dew formation.

Effects of Selection of planting Material on disease epidemiology

The use of seed, nursery stock, and other artificial propagative materials that carries various pathogens increases the amount of initial inoculum within the crop and favors the development of epidemics greatly. The use of pathogen-free or treated propagative material can reduce the chance of epidemics to a great extent. When a propagative material is exposed to pathogens and no any chemical fungicide is applied, the seeding material become a carrier or means of transmission of the pathogen and become a member of some diseases causal complex. Similarly, when a contaminated tool or equipment is used in the processing of a propagative material such as stem cuttings like in cassava and sweet potato, infective propagules of the virulent pathogens are directly implanted on to the propagative material. This serves as the source of primary inoculum and would definitely cause primary infection (Hadiza *et al.,* 2022). When a primary infection is developed and the pathogen is able to successfully undergo repeated reproductive generations, the secondary infection develops and that is the basis of an epidemy. Farmers should therefore be very careful on the selection of planting material and the tools they use for the processing.

Effects of Intercropping in Plant Disease Epidemiology

In agriculture, the act of cultivating more than one crop on the same farm having different life span and belongs to different families is termed as intercropping. Intercropping is also called polyculture, double cropping or sometimes, mixed cropping. According to Kebede (2017),these two or more crops can be of the same or different plant families or they can be of different varieties or cultivars of the same crop. Ordinarily, intercropping is aimed at so many agricultural benefits. Common advantage of intercropping is to increase crop yield on a given limited space, increase insect pest and disease control. And also provide variety of farm produce to the farmer. Thrupp (2002); Scherr and McNeely,(2008) have both reported that intercropping cause insects and other pests to be mislead by the canopy of an intercrop and not recognize the specific crop they use as a host which lead to the reduction of insect herbivory. It has also been reported that chemicals produced by other crops may drive insects away from the main crop or sometimes natural enemies of insects may be attracted by one of the crops in the intercrops. Examples; intercropping of maize/ cassava with cowpea, diseases incidence in legumes was reduced compared to sole cropped (Chemeda and Yuen, 2002; Sikirou and Wydra, 2008). Similarly, the finding of Degri *et al*. (2014) on pear millet intercropped with groundnut significantly ($p< 0.05$) reduced stem borer (*Chilo zacconius*) incidence compared with the control portion. Zhang *et al.* (2019) reported that intercropping consistently and substantially suppresses plant diseases. Boudreau (2013) mention five mechanisms in which intercropping decrease plant disease, which include interference with spore dispersal by wind or rain (as related to barrier effects of companion crops and host dilution in space),interference with vectoring of disease, alterations in micro-climate, changes in host physiology and resistance, and direct pathogen inhibition. Intercropping tomato with cowpea significantly reduced the incidence and severity of bacterial wilt compared with tomato alone (Michal *et al.*, 1997).

However, the act of inter cropping is a seriously demanding practice having a lot of technical applications. As such, any little mistake or misuse of the practice would eventually lead to increase plant disease and insect pests which usually serve as vectors.

Effects of Crop rotation on disease epidemiology

When different crops from different families are grown in a scientific manner each year in a field so that they follow one another, this practice is called crop rotation. Crop rotation can best be described as growing different crops in a recurring sequence on the same field. This practice when properly employed in a field has been found to significantly reduce or even eliminate and or eradicate a plant pathogen from an agricultural field. This is achieved by starving the pathogen for many cycles of seasons from coming in contact with a vulnerable host. Hanming *et al*. (2019) reported that habitat manipulation techniques such as intercropping, relay, and rotation can significantly improve disease and pest management. According to (Cook and Veseth, 1991) Crop rotation, i.e., growing different crops in different seasons in the same field is among the most effective ways to control soil-borne plant diseases. The rotation of different crops reduces the disease inoculum due to host absence, or other effects of the hosts, and organic residues that can affect the pathogens or antagonistic organisms (Hoitink and Boehm, 1999). Inoculum of pathogen is reduced drastically as result of absence of none host crop during growth of rotated crops (Garret and Cox, 2006). Rotation of upland maize and lowland rice affects the bacterial and archea colonization (Breidenbach *et al.*, 2017).

On the other hand however, crop rotation when misused (not employed appropriately) may tend to result into increase in disease incidence and severity of some diseases. Moura *et al.* (2019) reported that rotation of tomato crops with soybean, maize, sweet corn and bean crops was able to significantly reduce numbers of volunteer plants. Consecutive tomato cultivation promoted a higher number of volunteer plants for the next crop which in turn increase chances of bacterial spot of tomato epidemic. Sema & Ronis (2018) reported that crop rotation reduce the inoculum that cause take all of wheat disease in the experiment it shows that lowest level of disease infection was established in 2015, compared to 2014. In 2014, differences in disease infection between rotations were statistically significant at the 5% level. Wheeler *et al.*, (2019) conducted an experiment to determine the effectiveness of crop rotation in managing *Verticillium* wilt of cotton he found that continues cotton cultivation increased the incidence of wilt disease.

Crop rotation is key factor in impacting cropping system productivity, soil health, pest and disease management (Jalli *et al.*, 2021). Chen *et al.* (2017) conducted pot experiment to investigate the response of club root in Chinese cabbage to crop rotation with potato onion. The results showed that Chinese cabbage rotated with potato onion exhibited less club rot disease than Chinese Cabbage monoculture. Carrière *et al.* (2020) reported that crop rotation mitigate the impact of corn rootworm resistant to transgenic Bt cotton.

Effects of tillage on disease epidemiology

By and large, the term tillage refers to the mechanical act of turning the soil upside down and inside out so that the top soil is fully or at least partially moved and mixed with the sub-soil. Agriculturally, this practice is meant primarily to provide aeration between the soil particles, and to mix organic manure or fertilizer thoroughly between the different soil horizons for the reach of plant roots. It is also an effective method for the control of pathogens harbored by crop residues (Mehrotra and Aggarwal, 2003). However, tillage can equally predispose the pathogen to certain soil microbiota that may be antagonistic to plant pathogens. Example, early and shallow plough can result into accumulation and growth of inoculum, expose the pathogen and predisposes them to early germinating seeds such as cowpea, sorghum, and many cereals.

Effects of Improper Fertilizer Application on Plant Disease Epidemiology

Application of manure/fertilizer is a major cultural practice by farmers which involve the application of fertilizer or organic manure to improve growth and yield of any crop. However, the type of fertilizer and or manure, quantity and quality of fertilizer/organic manure applied, the time of application are all important key factors that determine the usability of the nutrients present in the manure/fertilizer and this is very important in the development of the plant and its enemies, the pathogens. Numerous investigations on the influence of soil nutrient upon infection suggest that excessive application of fertilizer having high levels of nitrogen decreases resistance of plants (Kutama *et al.*, 2013b). On the other hand, potassium in general increases resistance while the effect of phosphorous is variable. Excessive nitrogen favors infection of cereals to rusts, rice to blast diseases and of several plants to *Verticillium* wilt especially in the temperate areas. In cotton, excess of nitrogen is known to aggravate Damping off of their seedlings. The root damage due to damping off of the seedlings caused

by species of *Pythium* can be minimized by adding phosphorus to the soil. Application of fertilizer with high Potassium confers resistance. Potassium deficiency increases the severity of many diseases. Formation of galls and outgrowths are favored by increase in potassium level. Fusarium wilt of cotton caused by *Fusarium oxysporum* is severe in potassium deficient soils. The disease can be overcome by increasing the potash level.
Singh *et al*. (2001) reported highest disease index of early blight at higher dose of nitrogen in tomato and lowest disease index in unfertilized plots. Kumar and Sugha (2003) studied the effect of nitrogen on Phomopsis disease of Brinjal and noticed a positive relation of leaf blight and fruit rot with increase in nitrogen nutrition. Nitrogen as ammonium sulphate suppressed the progress of disease.

Effects of Poor or No weeding on plant disease epidemiology
A major human on-farm cultural practice is weeding. It is the act of removing weeds on the farm that compete for water, space, nutrients and air with the main crop of desire. When weeds are removed, it eventually allows the main crop to proliferate comfortably. On the other hand, presence of weeds on the farm poses a lot of harvoc vis a vis the growth and life of the desired crop. Weeds create a conducive atmosphere for the growth of some insect pest such as aphid that transmit rosette of groundnut, white fly responsible for mosaic of cassava (Musa *et al*., 2021). Higher weeds infestation reduces air movement around the fields/ crop canopy, and increases air humidity which leads to increased leaf- wetness and higher possibility of spore germination and development of pathogen. This is similar to the report of Shafaullah *et al.* (2011) that the rice blast disease severity on different varieties /lines were having significant correlation with environmental variables (maximum temperature, minimum Temperature, rain fall and relative humidity). And to vindicate this, Singh and Bhatt (2006) had earlier demonstrated that good cultural practices including; altering planting dates, removal of crop residues, weeds management, planting of disease free seeds /resistant variety can serve as important options in preventing rice blast disease. Similarly, it has been reported that the incidence of downy mildew in millet caused by *Sclerospora graminicola* was relatively higher in weedy/bushy than in clean millet fields (Zarafi and Emechebe, 2005) and this is similar in maize (Kutama *et al*., 2010) as this increases the humidity of the fields.

Effects of Spacing/ Planting density on plant disease epidemiology:
This literally refers to the distance between plant stand on a farmland. The space between the plants is a very important factor that decides for the growth and dissemination of pathogen propagules in most agricultural fields. In many cereal crops for example, wider spacing is recommended than for most creeping and leguminous crops. When cereal crops are densely planted, there is usually a lot of rise in relative humidity and consequent dew formation. This condition favors the development of diseases such as downy mildew in pearl millet caused by *Sclerospora graminicola*. *Phytophthora infestans* (Potato blight) and other downy mildews require high atmospheric humidity throughout the disease period. Pathogens such as *Peronoscleropora sorghi* of sorghum and maize and many other soil pathogens e.g., *Rhizoctonia*, *Sclerotinia*, and *Sclerotium* all require high humidity for their sporulation.
Some bacteria e.g., *Erwinia* and fungi can germinate, penetrate, and cause infection even when there is only high relative humidity in the atmosphere surrounding the plant. In powdery mildew of Water melon and Paw Paw, spore germination and infection are actually lower in the presence of free moisture on the plant surface than they are in its absence.
However, in some legumes such as Ground nut and Cowpea, close spacing is mandatory for the better yield of the crops as wider spacing encourages the transmission of Rosette and mosaic viruses by Aphid and White fly, respectively (Hayatu *et al*., 2014).

Effects of Improper or no Quarantine on plant disease epidemiology

Quarantine requires checking and monitoring of any imported agricultural commodity or material to be used for agricultural production into a region or country before it is accepted and introduced to the farmers. It involves careful monitoring of the health status of that imported material to a certain span of time that will satisfy its authenticity. The essence is to prevent any unwanted or strange character from getting into a foreign country or region where it was not there before. However, improper quarantine can lead to the introduction of new pathogens or its propagules into an area and this would affect the disease epidemiology positively. Looking at the contemporary world nowadays, worldwide travels have become very easy and this has also increased the movement of seeds, tubers, nursery stock, and other agricultural goods. These travelling activities have increased the possibility of introducing pathogens into areas where it was not there before or where the host plants have not had a chance to evolve resistance to these pathogens because the latter is strange in the area or that the host plant did not encounter such pathogen before (Kutama *et al*., 2013a). In such cases, the pathogens frequently lead to severe epidemics. Examples are Chestnut blight, Dutch elm disease, and Citrus canker caused by the bacterium *Xanthomonas campestris* pv. *citri*. Between 1990 to 1994, Maize downy mildew pathogen (*Peronosclerospora sorghi*) was introduced to Nigeria from abroad because of poor quarantine.

In the same vein, it is reported that spores of both fungi and bacteria could be transported thousands of kilometers by humans, plants, simple farm tools, and animals (via seeds and feathers), or by high wind events, such as hurricanes (Golan and Pringle, 2017). This case has been illustrated in 2006 by Soybean rust movement from Brazil to the Ohio valley of United states via Hurricane Ivan (Isard *et al*., 2007).

CONCLUSION

It is evident that apart from the three factors of disease development that decides for the epidemy of any disease, (namely; environment, Host and pathogen) human interference and or cultural practices usually carried out regularly for the purpose of crop production are a major contributing factor to disease spread in a defined geographical location. Perhaps, this can be considered as the fourth factor of disease epidemiology and can change the disease triangle to a square shape as this factor sometimes decide the longevity and effectiveness of each of the factors in the normal disease triangle; (environment, Host and pathogen). Based on this therefore, farmers need to be extra careful when dealing with any of these agricultural practices as misuse of any can bring about disease spread and an unexpected epidemy of a disease in an area.

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