The Significance of Crop Disease Outbreak to Society: A Review

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Abstract

Plant disease outbreak is of much concern to society as a whole as it has a huge impact on food security. A stable food supply is needed for the mass and improve the health outcome of people. Currently, plant diseases are spreading at a higher rate due to change in climate, transmission with global food trade network, and evolution of new races of pathogens. In order to tackle these challenges, a new set of tools that include disease surveillance and improved detection technologies are needed. Under the current setup of crop disease management system and Ethiopian government initiatives to boost-up crop production, the likelihood for disease outbreak is increasing. Therefore, all options of disease management system must be reviewed and an appropriate program must be launched and ensure its enforcement in an organized manner.

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Introduction

It has been said that human beings (as well as animals) exist on earth solely as guests of the plant kingdom because only green plants can convert the energy from the sun into food. We depend on plants not only for food but also for our clothing and shelter needs, as well as for numerous luxuries. Medicinal plants are sources of drugs. Ornamental plants make-up a multi-industry. Thus, when diseases kill plants, all other forms of life on earth are adversely affected.

Damages to plants and plant products, commonly with an associated economic effect by causing a reduction in income for crop producers and distributors and higher prices for consumers, may result in hunger and starvation, especially in less-developed countries where access to disease control methods is limited. As a result, annual loss of 30 to 50 percent are not uncommon (FAO. 2019;Fedoroff, 2015).Global yield losses due to crop pests and diseases on food crops are large, with mean losses ranging from 21.5% in wheat, 30.3% in rice, 22.6% in maize, 17.2% in potato, and 21.4% in soybean (Savary *et al*., 2019).

Plant diseases may limit the kinds of plants grown and industry development in an area. As an example, coffee plantation is abandoned in Ceylon (Sri Lanka) due to a disease called *coffee rust* and had forced farmers to grow tea instead (Valent, 2021). Diseases also have effects on reducing the quality and quantity of crop production. In addition, plant diseases may make the crops or plants poisonous to humans and animals. For example, ergotism poisoning on human and some animals is due to ergot formation on rye seeds caused by a fungus known as *Claviceps purpurea (*https://en.wikipedia.org/wiki/plant_pathology;Sandhuand Kaur,

2019). Thus, in general, occurrence of plant diseases in a country may cause financial losses, incur expenses of labor, and may involve chemical costs to control it (Delgado *et al*., 2017).

Historical Significance of Plant Disease Outbreak

Plant diseases are of global concern and exact a heavy toll on food production and affect the social and political stability of nations. The outbreak of plant diseases has increasingly threatened food security to the vulnerable in many areas of the world and, as a consequence, it had led to famines and mass migration in some regions. A phenomenal example is the devastating outbreak of late blight of potato in 1845-46, caused by a type of fungus known as *Phytophthora infestans*, brought about the Great Famine resulting to starvation, death and mass migration of the Irish people ((https://extension.unr.edu/publication.aspx?publD=2647; Sieff, 2019).

The recent coffee rust outbreak caused by a fungus known as *Hemilea vastatrix* in Central America provides yet another example of the displacement of people due to an emerging endemic plant disease and climate change. Yield losses in coffee greater than 50% occurred in some regions of Central America and over 400,000 coffee workers lost their livelihoods in the coffee sector in Honduras, El Salvador and Guatemala, leading to hunger, poverty, and increased migration (Avelino *et al*., 2015).

The southern corn leaf blight caused by another fungus named as *Bipolaris (Heliminthosporium) maydis* (the imperfect state of *Cochlibolus heterostrphus)* is another spectacular example of a major disease epidemic that affected around 85% of the total corn crop in the United States of America during the 1970 harvest season (((https://extension.unr.edu/publication.aspx?publD=2647; Valent, 2021).

Dutch elm disease epidemic caused by *Ophiostoma novo-ulmi*,a fungal infection has affected many species of elm (Ulmus) trees in America. The fungus infests the vascular system of the tree, which blocks water flow within the plant and mimics drought stress. The elm bark beetle acts as a vector and transmits the disease from tree to tree (Valent, 2021).

A number of other crop diseases were reported to have historical significance in causing heavy losses of produce over rather large areas and resulted in untold sufferings to human beings (Savary *et al*. 2019).

a. Brown spot disease epidemic of rice caused by *Bipolaris (Helminthosporium) oryzae* brought about Bengal famine in 1943;
b. Coffee rust *(Hemilea vastatrix)* in Ceylon (now Sri Lanka) has destroyed vast coffee plantation in the past and forced the country to abandon coffee production and switch to tea production;
c. *E*rgot poisoning in Europe (875A.D) which is acquired from eating bread made from infected rye;
d. Powdery and downy mildews of grape in France 1851, 1878);
e. Panama disease of banana in Central America (1900 -65); and
f. Stem rust of wheat (1916, 1935,1953 -54).

Main Factors for Plant Disease Development

Plant diseases are classified into two types: abiotic or non-infectious diseases and biotic or infectious diseases. Abiotic diseases are caused by conditions external to the plant, not living agents. They cannot spread from plant to plant, but are very common and should be considered when assessing the health of any plant. Example of abiotic diseases include nutritional deficiencies, soil compaction, salt injury and sun scorch, etc. ((https://en.wikipedia.org/wiki/plant_ pathology).

Biotic diseases are caused by living organisms – plant pathogens when they infect plants. The main pathogens include several types of microorganisms such as bacteria, fungi, viruses, nematodes, mycoplasmas, and some parasitic higher plants. The pathogens can spread from plant to plant and may infect all types of plant tissues, including leaves, shoots, stems, crowns, roots, tubers, fruits, seeds and vascular tissues ((https://en.wikipedia.org/wiki/plant_ pathology).

Mode of Infection

Locating a proper host to cause the disease is the first prerequisite of a pathogen. In many cases, this is a random process depending upon chance contact between pathogen propagule and a susceptible host. Many plant pathogenic fungi produce air-borne spores that are dispersed by air currents. Similarly, pathogenic bacteria may be blown or splashed between plants by wind-driven rain splashes. In these cases, successful contact with a susceptible host relies upon the huge number of pathogen propagules produced, which increases the probability that at least some will land on a susceptible host.

For many plant pathogens a capacity to breach the cell walls of their hosts is not required for entry, since they rely on wounds, natural openings or vectors. However, many fungal pathogens achieve entry by mechanical force or enzyme activity or a combination of both (https://en.wikipedia.org/wiki/plant_ pathology).

Plant Disease Detection

Pathogen-related food losses are today responsible for a reduction in quantity and quality of yield and the decrease in value and financial returns. In order to minimize the effect, “early detection” in combination with “fast, accurate and cheap” diagnostics have also become the new mantra in plant pathology, especially for emerging diseases of challenging pathogens that spread, thanks to asymptomatic individuals with subtle initial symptoms but are then difficult to face (https://ieeexplore.ieee.org/docment/9399342).

Common methods for the diagnosis and detection of plant diseases include visual plant disease estimation by human raters, microscopic evaluation of morphology features to identify pathogens, as well as molecular, serological and microbiological diagnostic techniques (https://ieeexplore.ieee.org/docment/9399342; Muhammed *et al.*, 2019).

The plants need to be monitored from a very initial stage of their life cycle to avoid such diseases. The traditional method being followed for this supervision is naked eye observation which is more-time consuming, expensive and requiring a lot of expertise. So, in order to speed-up this process, there is a need to automate the disease detection system. The system needs to be developed using image processing techniques. Thus, many researchers have developed systems based upon various techniques of image processing ((https://ieeexplore.ieee.org/docment/9399342; Ilaria Buja *et al.*, 2021).

Modern approaches, such as Machine Learning and Deep Learning algorithms, have been employed to increase the recognition rate and the accuracy of the results. Machine learning is a subset that falls under the set of artificial intelligence. It entails the use and development of computer

systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyze and draw inferences from patterns in the data (Ilaria Buja *et al*., 2021).

It is rather inexpensive to detect plant diseases using machine learning. Various researches have taken place under the field of machine learning for plant disease detection and diagnosis under different approaches, namely, random forest, artificial neural network, support vector machine (SVM), fuzzy logic, and K-means (Shima *et al*., 2018).

Deep Learning is a subset of Machine Learning. The advantage of Deep Learning over Machine Learning is that it does not need to worry about domain expertise as no feature engineering is required in this, unlike traditional machine learning approaches. The core of Deep Learning is artificial neural network (ANN). Artificial neural networks are mathematical models that replicate with their neurons and synapses interconnecting them with the general principles of brain function (Muhammed *et al*., 2019; Pelczar, 2021).

Deep Learning model is able to detect many diseases from plants using pictures of their leaves. Provided that sufficient data is available for training, Deep Learning techniques are capable of recognizing plant leaf diseases with high accuracy. The process basically requires application of augmentation on dataset to increase the sample size. Later, Convolution Neural Network (CNN) is used with multiple convolution and pooling layers. Plant Village dataset is used to train the model. After training the model, it is tested properly to validate the results (https://ieeexplore.ieee.org/docment/9399342; Ilaria Buja *et al*., 2021;

Muhammed *et al.*, 2019). In order to utilize these technologies for detecting diseases on plants, one has to be proficient enough through training.

Plant Disease Epidemics

The contributing factors for plant disease outbreak and spread or epidemic of infectious diseases are availability of infectious pathogens, susceptible host, and favorable environment (Isard *et al*., 2007; Valent, 2021).

A plant disease epidemic is a dynamic process. It initiates on one or a few plants and then, if all environmental and other factors are favorable, increases aggressively and spreads over a large geographic area until it finally declines.

Epidemics rarely occur in natural plant communities. It is because in such communities, the host (landrace) and pathogen have co-existed for thousands of years and, as a result, some form of equilibrium has evolved between the two. However, the domestication process of plants for human use, along with the gradual intensification of agriculture, has altered this balance. Cultivation of selected varieties of a single crop species has loaded the pathogens with virulence by providing genetically uniform hosts. These monocultures present an ideal situation for the rapid development of pathogen, which is virulent on the crop genotype concerned (Isard *et al*., 2007). Monoculture of susceptible coffee varieties, low coffee prices, and climate change in Central America led to the spread of coffee rust, mentioned above, to higher elevations where farmers were ill-prepared and lacked access to fungicides to control the disease. Most of the historical disease outbreaks reported above occurred due to these factors.

When virulent strain of the pathogen, favorable environment, and susceptible host occur simultaneously at a region, the likelihood of outbreak of disease is much greater. However, an epidemic of disease on crop plants, after its full fledge development and severity, commonly comes to a stage where it starts declining. This is because no epidemic remains forever in a population. The reasons that enable the epidemic to decline are non-availability of more host plants susceptible to further infection and disease development, decline of proneness in the host to infection at a particular stage of growth, change in weather condition, or a reduction in pathogen aggressiveness.

Crop Disease Challenges in Ethiopia

Almost all food crops currently under cultivation in Ethiopia are prone to infection by diseases circulating in the region, but the degree of infection varies from species to species and from place to place. Our readiness to combat them, in case they reach an epidemic level, needs to be assessed (Dereje and Yaynu, 2001).

Currently, the production of some of the crops are being promoted diligently, hopefully with sufficient preparation to safeguard them if any unforeseen disease outbreak occurs in the region.

As much as we fully support the current initiative to be self-sufficient in food crops, we need to be cautious in not propagating devastating pathogens by providing them means for their multiplication. The wheat crop, for example, is currently getting more attention by expanding its production to meet the country's need. However, the crop is exposed to three devastating diseases, namely, stem rust of wheat (caused by *Puccinia graminis triciti)*, leaf rust *(Puccinia recondita)* and stripe rust *(Puccinia striformis)*. All three

types are reported to be occurring in Ethiopia and produce air-borne spores which can travel long distance (sometimes from one country to another) carrying the power to initiate infection if they find the right environment and a susceptible host variety (Dereje and Yaynu, 2001).

Similarly, other crops could face similar challenges. We have witnessed such a trend on coffee crop, potato, beans and some of the vegetable crops cultivated in the country.

Some pathogens are being introduced into the country intentionally or unintentionally due to lack of knowledge. As an example, coffee berry disease *(Colletotrichum coffeanum)* was known to have been introduced into the country by such means. It has cost the country a large sum of money in order to import chemical fungicide to combat the disease (Dereje and Yaynu, 2001).

In crop breeding programs, there is a tendency to narrow down the genetic diversity of some important food crops with the intension to increase crop productivity. It is important to note that most of the crops survived the onslaught of many of the diseases in this country due to their genetic diversity which has enabled them to withstand damage. The narrowing down of the genetic base of the landraces in the breeding program tends to lose some important genes resistant to some races of pathogens. Therefore, one has to consider this fact in crop breeding programs in order to counter the erosion of the genetic pool for disease resistance.

New races of pathogens appear from time to time and some of them are highly virulent and easily propagate to cover wider areas within a short period of time and cause a devastating effect on the crop.

Management of Plant Diseases

It is estimated that food production will need to increase by 60% by 2050 to feed the estimated 10 billion people expected on earth (FAO, 2019; Valent, 2021). An increase in production along with a reduction in food loss due to pests and pathogens and food waste will be needed to meet demand (Delgado *et al*., 2017; Savary *et al*., 2019).

Plant disease cannot be entirely eradicated, but it can be controlled and reduced below an economic threshold level. As discussed above, for crop disease outbreak to happen, the three conditions, i.e. virulent pathogen, susceptible host, and favorable environment must be present. If anyone of these conditions is missing the disease will not happen even if two conditions are present (https://extension.unr.edu/publication.aspx?publD=2647.

Plant disease is best managed through an integrated approach which includes a grouping of cultural, mechanical, biological and chemical practices. On the basis of this assumption, they are grouped into six categories: exclusion, eradication, protection, resistance, avoidance, and therapy.

The exclusion practice involves preventing the disease from developing within a specific area. The method involves excluding the pathogens, vectors and infected plants out of the disease-free areas susceptible to the plant diseases. In essence, this is preventing the disease from entering the

area where the plants are growing. A good example of this practice is enforcement of inspection of all plant materials due to enter into the country through quarantine at the port of entry.

Eradication consists of eliminating, destroying or inactivating disease organisms (pathogens) after they had become established. The method involves the destruction of infected plants, soil disinfection by fumigation, and storage bins disinfection as well as cleaning farm equipment. It also involves reduction in the level of infestation by cultural practices, such as sanitation, removing diseased plants or plant parts, rotating crops, eliminating weeds or other plants that may serve as alternate hosts for the disease, and discouraging or preventing insect vectors.

Protection is an establishment of a chemical or physical barrier between the host and the pathogen. In many cases it involves the use of chemical fungicides, insecticides or herbicides to manage the problem.

Resistance of the host plant is achieved by altering the genetic make-up of the host through breeding to make it less susceptible to the pathogen. Two types of plant resistance are recognized – vertical resistance and horizontal resistance. Vertical resistance provides very high level of resistance or immunity to specific strain or race of the pathogen. It can easily succumb to the disease if new race appears within the area. However, horizontal resistance is considered as having lower level of resistance to many strains of the pathogen. This type of resistance has high level of tolerance to many races of the pathogen.

Avoidance refers to several types of cultural practices that help avoid the potential for infection. The practice involves planting date selection, seed-bed preparation, water management – avoiding poorly drained soils, shades

and other factors that increase the susceptibility of plants to disease, providing adequate irrigation, fertilization, and space for each plant, and holding plants carefully to prevent injury, as the injury may later be the access point for a pathogen.

Therapy is usually adopted for vascular diseases on food crop trees. It is usually achieved by incorporating a chemical control agent into the physiological process of the plant to reverse the progress of disease development after infection has occurred.

Conclusion

The magnitude of diseases on crops has been noted and the need for appropriate measures to tackle the challenges has been emphasized. The current trend of agricultural development and boost-up in crop production to meet the demand in Ethiopia without appropriate preparedness to combat diseases is likely to bring about unforeseen disaster. More comprehensive surveillance strategies for plant diseases that include strategic partnership among research universities, development agencies, nongovernmental organizations, and the private sector are needed. Research programs focused on disease surveillance and epidemiology for the high impact plant pathogens on major food crops, such as, wheat, barley, potato, corn, and rice are needed to prevent the spread of plant pathogen. New outlook can be predicted with disease surveillance; and data can be used to determine the origin of outbreak strain. Modern technology to disease detection must be developed and streamlined in their usage among researchers and academic institutions. Appropriate management strategies must be developed and executed for each disease type when required.

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