# A Review: Impact of Climate Change on Plant Pathogen and Disease Outbreaks

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## 1. Abstract

One of the biggest worldwide dangers to the environment is climate change, which has an impact on agriculture, ecosystems, plant health, and plant-pathogen interactions in general. The temperature, precipitations, and atmospheric and carbon dioxide levels are all still being changed by global warming. The modification of environmental conditions continues to result in increased pathogen risk and severity during disease outbreaks. This review explores plant pathogen dynamics under changing climate conditions by discussing alterations in environmental conditions and impacts on pathogen virulence and distribution susceptibility of host plants. Predictive modelling and prevention methods are also covered to avoid subsequent outbreaks. Climate change has significantly affected the dynamics of plant pathogens, particularly regarding temperature, humidity, and precipitation patterns, which increase the severity and spread of many diseases. A plant disease outbreak is made more likely by more frequent extreme weather events that have been a direct outcome of changes in the climate. Plenty of plant diseases have travelled into new species and areas as a result of increasing worldwide temperatures, bringing diseases to previously exclusively warmer environments. An adaptive approach to agricultural activities is required since climate change impacts the prevalence and severity of plant diseases, which also changes how well prevention and control operate. The interaction between plant diseases and climate change is thoroughly examined in this analysis, which also carefully examines the dynamics of the disease-climate shift. These insights besides providing the vision for the development of strategies effective against climate change-related adversities toward plant diseases promise great things for building up crop production resilience to increasingly severe environmental challenges around the globe.

**Keywords:** Climate, Change, Pathogens, Disease, Dynamics, Geographical, Mitigation.

2. **Introduction:** From modifications in pathogen evolution and host-pathogen interactions to the emergence of novel pathogenicity strains, the effects of changing temperatures on disease are considerable. **(Singh *et al.*, 2023)**. Nearly every element of biological systems is impacted by climate change, and the wellness of plants is no surprise. Pathogens viruses, bacteria, fungi, and oomycetes play a significant role in influencing plant productivity and food security. Such pathogens are changing behaviour, virulence, and distribution as climate changes the natural environment. The dynamics are important in the development of sustainable agriculture and the protection of global food systems. As environmental conditions change, pathogens evolve to be the new environment and could potentially cause new diseases or the reappearance of previously controlled diseases. Pathogen virulence can also be impacted by climate change. At the same,

climate change continues to be one of humanity's biggest challenges, resulting in an estimated 1.2 trillion US dollars annually while resulting in a median loss of nearly 0.4 million agricultural resources annually **(EPA, 2023).** As the worldwide mean temperature has gone up by almost 0.74$^0$C over the past century atmospheric carbon dioxide (CO2) concentrations went up from 280 parts per million (ppm) in 1750 to 418 ppm in 2022, the effect this has on agriculture is profound **(EPA, 2023).** Many crops' growth and output are greatly impacted by these fluctuations, which also alter their severity. Various plant diseases are being produced and spread, putting our food security at harm (Moullect *et al.*, 2019). There is an urgent need for new crop types given the extent of the climate's volatility and the effects it has on crop plants and their phytopathogens. However, on average, this process of change takes 20 years (Sreenivas *et al.*, 2022). The reported changes have major impacts on ecological and agricultural systems. In addition to reducing crop output, the development of plant diseases also causes biodiversity loss, which jeopardizes essential ecosystem services (Kashyap *et al.*, 2018; Singh *et al.*, 2023). Understanding the nuances of how climate change is affecting the dynamics of plant diseases has become important. This understanding service is a starting point for creating practical solutions that lessen the detrimental impacts on integrity and sustainability in both natural agriculture. Likewise, several kinds of diseases that are now restricted by the need to overwinter, including Puccinia graminis f. sp. Tritici's wheat stem rust, can spread as temperature rise **(Singh *et al.*, 2023)**. Nonetheless, it was shown that throughout 30 years during which the summer temperatures increased yearly, Triphragminu ulmarie, a rust disease that diseases meadowsweet, or Filipendula ulmaraia, went local in some areas **(Zhan *et al.*, 2018).** About climate forecasts, there is a greater likelihood of severe occurrences including heat waves, droughts, and storms that will last longer and be more intense **(Cook *et al.*, 2016).** As a result, there are numerous instances of disease breakouts in other areas. Furthermore, climate change significantly changes a host's vulnerability to disease, changing the planting of host cultivars **(Moullec *et al.*, 2019).** Changes in mean temperatures, adjustments to yearly precipitation patterns, and prolonged droughts will be the earliest signs of the effects of the advent of global warming. On the other hand, environmental stressors brought on by climate change may plants more vulnerable to colonization by bacterial and fungal pathogens, which ultimately result in plant mortality through harm to the health of plants **(Devendra *et al.*, 2012).** This time frame may present difficulties for the processes of plant growth and development, which could result in crop losses **(Ebi *et al.*, 2016).** The dynamic landscape of the shifting interactions between the pathogens and their environment is another important contributing factor that leads to new emergency events **(Velasquez *et al.*, 2018).** To attack and control host plants and encourage the spread of diseases, pathogenic organisms heavily utilize a variety of structures and substances (**Ogbonna & Umunna, 2017).** By activating defence systems against invasive pathogen attacks, the plants fight back against this invasion **(Olori-Great & Opara, 2017)**. The relationship between Colletorichum gloseporioides and avocado fruit, for instance, is an excellent instance of this nuanced interaction. In this case, the fruit's epicatechin serves as a defence mechanism against the fungal laccase proteins **(Djami-Tchatchou *et al.*, 2013).** Multidisciplinary impacts on disease dynamics are highlighted by the changing gene pathogenicity of diseases across geographic locations **(Djami-Tchatchou *et al.,* 2013; Grassi *et al.,* 2009Mayek-Perez *et al.,* 2002)**. As they evolve to overcome the host's defences and ultimately result in disease, abiotic stressors including salinity, drought, and high general have an impact on both plant defence mechanisms and pathogen virulence pathways **(Deohlemann *et al.,* 2017).** However, in different ecological niches, abiotic variables control pathogen dynamics and control plant defence mechanisms **(Adhikari *et al.,* 2013)**. To maintain food security and lessen the detrimental effects of disease on essential food crops, it is critical to comprehend the relationship between climate change and plant diseases from an agroecological standpoint. By taking them into account and modifying mitigation tactics to lessen likely through the creation of resistance cultivars, innovative control approaches, and adaptive ways, current agriculture can improve and produce more food. Promoting climate-resilient crops and enhancing prevention and control initiatives are the two main goals of the substantial research and development expenditure required to meet the serious issues related to climate-driven changes in disease dynamics **(Desai *et al.*, 2021).** The following involves growing cultivars that are more resistant to disease and using modern methods for control, such as biological agents and IDM systems **(Chakraborty & Newton, 2011).** Given the shifting disease environment driven by climate change, this highlights the necessity to develop forecasting models that can reliably predict the severity of key diseases affecting important crops in realistic agricultural environments. This in return demands the application of effective disease control techniques in addition to environmentally friendly agricultural practices **(Singh *et al.,* 2023).** The complicated causes of climate change, such as emissions of greenhouse gases, deforestation, and human activities, are thus described in this overview along with how they change environmental factors like soil pH and temperature. Shifts in those factors can have a major impact on disease processes, pathogen virulence and exchange, host risk, and the condition of plants. **Dik AJ & Wubben JP (2007)** Climate change can drastically modify the life cycle and reproduction of plant diseases. The timing and duration of pathogen life phases can be impacted by changes in conditions such as humidity, temperature, and precipitation patterns, factors that can change the epidemiology of diseases. Warmer temperatures, for instance, may decrease the duration that viruses need to incubate, allowing faster and more numerous cycles of disease. Pucciniastriiformis, the pathogen that causes wheat rust, has proved this by growing more quickly and producing more spores at warmer temperatures, which may lead to more severe outbreaks. The survival and spread of disease spores can be affected by shifting precipitation patterns. The fungus Botrytis cinerea, which causes grey mould, is an example of how higher humidity & precipitation can create the germination and spread of pores in various crops.

**(Elshahat MR *et al.*, 2016)** Environmental factors have a considerable impact on plant-pathogen interactions. The onset and spread of plant diseases can be affected by multiple elements, such as soil conditions, light, humidity, and temperature. High humidity and moderate temperatures, for example, often promote fungal pathogen infection and sporulation, whereas low humidity and high temperatures can hinder fungus growth. The pH and moisture content of the soil also affect the survival and contagiousness of soilborne disease in nematodes and certain bacteria. For instance, drought is an environmental stressor that can weaken plant defences and increase exposure to diseases. **(Burdon & Zhan, 2020)** Climate change is currently humanity's greatest conservation issue. In various species of animals and plant populations, rapid and significant changes are now taking place in temperature, precipitation, evaporation patterns, and the frequency of severe occurrences. From the standpoint of agriculture, these modifications impact the crop spread by region and diseases linked to them, as well as the range and consistency of production. The consequences for biological categories and environments might appear less obvious presently but potentially more concerning because of the potential to set off a domino effect. A single pathogen species' change in fate—a rise or fall which results in global loss could be eclipsed through consecutive rises before falls this leads to "knock-on" consequences throughout entire plant species in terms of host suitability. **(Zhan J *et al.*, 2018)** A 26-year study of 230 or so northern Swedish coast characterized by areas covered by Filipendula ulmaraia provides a case study of how disease epidemiology in a natural setting may be harmed through climate change. The incidence and severity of the rust (Triphragmium ulmariae) infection varies from patch to patch and from year to year. A consistent rise in summer temperatures has a strong correlation with a greater rate of local pathogen extinction, according to these long-term data. In addition, the rate of development for host populations free of diseases is higher than that of sick populations. The local extinction of this virus might therefore have a significant impact by changing the community's structure.

**This review paper deals with three topics:**

1. The topic of the impact of worldwide warming on pathogen dynamics; the link among climate factors to plant disease outbreaks, and possible mitigation possibilities and prediction models for the future.
2. Climate Change and Plant Dynamics Temperature and Pathogen Development. Probably one of the easier effects of global warming, leading to rising temperatures magnitude of overheating of the planet most probably to reproduce much faster, and possess a shorter incubation time, and sometimes that means being virulent **(Garrett, Dendy *et al.*, 2006)** For example, in fungi such as Puccinia spp, high temperatures favour their increase; thus, diseases tend to have more frequent and intense outbreaks.

**<u>Humidity and Disease Epidemics</u>**

Humidity levels greatly impact the spread and proliferation of many plant pathogens, especially fungal and bacterial diseases. Increased moisture brought by changes in rainfall patterns can improve the quantity of the surfaces of the plants, creating a perfect pathogen proliferation environment (Research has shown that the proliferation of diseases like downy mildew and powdery and mildew increases with moister environments).

3. **<u>CO2 concentration and host-pathogen interactions</u>**

The increased atmospheric $CO_2$ levels influence plant physiology through increased photosynthesis and altered plant architecture. Such alterations may reduce host susceptibility to pathogens. Although some studies indicate that enhanced $CO_2$ concentrations may improve a plant's defence mechanisms, it can also result in denser plant canopies, which might create a microclimate that fosters survival and transmission of pathogens. (General mention of studies on increased $CO_2$ effects on pathogen survival).

**Changes in the geographical distribution of plant pathogen** Generally speaking, as global temperatures escalate, most pathogens are attacking new areas where they may not survived before. **(Zhan *et.al.*, 2018)**, Phytophthora infestans case). Tropical pathogens are moving closer to temperate regions thus making crops vulnerable in areas that hitherto had low–pressure diseases. In particular, the cause of plant late blight, which is caused by a bacteria called phytophthora infestants has been found in cold-climate conditions due to more favourable winters and longer duration of the growing season. These geographical shifts pose a critical threat to food security, mainly in unprepared areas. Such changes require that farmers and policymakers anticipate such shifts and come up with adaptive strategies for managing risk.

### 4. Climatic Extremes

Climate change, apart from long-term environmental change, also promotes extreme climatic events such as droughts, floods, and storms. These kinds of events can cause sudden outbreaks of plant diseases through the following mechanisms: Physical damage to crops which may provide entry points to pathogens. Changes in the local ecosystems may stimulate the vector's growth and multiplication. Plant stress inherently weakens the defense against pathogens (Cook *et al.*, 2016). Drought stress has been proven to predispose plants to diseases related to pathogens such as Fusarium asp. Heavy rains also tend to aggravate soil-borne diseases (Devendra *et al.*, 2012).

### 5. Emerging Pathogens and Climate Change

Directly, it is bringing new pathogens forth. Warmer temperatures and greater trade and travel allow for new pathogens to be established in new areas. For example, the bacterium (Xylella fastidiosa) causes damage to Oliver trees in southern Europe. It established a presence in warmer climates and threatens the Mediterranean agricultural sector. Whereas these pathogens have hitherto been considered relatively insignificant, localized entities, changing conditions may make them significant threats that would demand vigilance and repaid response measures.

### 6. Predictive modelling for management Strategies

With increased climate change risk leading to outbreaks of plant diseases, there should be predictive modelling that uses a model that incorporates climatic variables, pathogen life cycle, and crop phenology that will help the farm develop in advance preparedness towards outbreaks (Singh *et al.*, 2023). For instance, predicting wheat rust outbreaks with climatic data like temperatures and humidity levels for farming measuring to be taken.

Management Strategies to Overcome Climate Change- induced disease outbreaks. Breeding and genetic engineering for developing resistant crop varieties. Chakraborty & Newton (2011), indicated that crop rotation and diversification with a strategy that reduces that reduces pathogen buildup. According to Desai *et al.(*2021), accurate irrigation and fertilization applications further reduce plant stress, thus increasing resistance towards pathogen attack.

### 7. Conclusion

Climate change alters the landscape of plant disease, making it more frequent and severe and the attacks more geographically widespread. Temperature increases, changes in precipitation and atmospheric CO2 will mean complex interactions that are problematic to manage. (Garrett *et al.*, 2006; Chakraborty & Newton, 2011).

Therefore, predictive, models must be integrated to safeguard global agriculture; management practices need to be integrated into new and innovative, and there has to be a collaboration between scientists, policymakers, and farmers. Future research in this area should be aimed at revealing the mechanisms through which pathogens are adjusted to the genetic and ecological situations of changing climates and finding sustainable solutions to mitigate such impacts. The fact that the changes could be kept ahead can ensure food security and stable ecosystems despite the uncertain situation regarding climate.

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