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Review Article

The Emergence of New Phytopathological Diseases Due to Climatic Changes

Labaran H.B.[1*], Sultan Z.[2], Gambo S.B.[1], Ali M.[1], Sa'adu S.K.[3], Zainab A.D.[4]

[1]Department of Biological Sciences, Rabiu Musa Kwankwaso College of Advanced and Remedial Studies, Tudun Wada, Kano State
[2]Department of Biological Sciences, Northwest University Kano, Kano State
[3]Department of Geography, Rabiu Musa Kwankwaso College of Advanced and Remedial Studies, Tudun Wada, Kano State
[4]Department of Biological Sciences, Kano State College of Education and Preliminary Studies (KASCEPS)

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Abstract: The emergence of new phytopathological disease is of great concern in line with the continuous changing climatic ecosystem associated with industrialization and urbanization. Plants respond differently to biotic (diseases) and abiotic factors (climatic factors). Climatic changes alter the infection cycle of most plant pathogen weather monocyclic or polycyclic. However, understanding the impacts of such changes on disease manifestation is of greater importance. This paper aims to explore reported cases and influence of new emerging phytopathological diseases as relative to climatic changes. The paper emphasizes understanding the development of new diseases under continuously changing temperature, level of carbondioxide, moisture level and relative humidity amongst others. The effects of climatic changes on the general plant photosystem are also explored. The paper concludes with management strategies employed by countries to mitigate pathogen emergence such as establishment of regulatory measures and quarantine bodies and phytosanitary.

Keywords: Emerging disease, phytopathological disease, abiotic factors, climatic changes.

INTRODUCTION

Emerging phytopatholoical diseases are original cases or group of cases that are newly recognized in an area and can increase fast in incidence and severity (Avila-Quezada *et al.,* 2018). They represent the initial presence of a disease in crops and when left unchecked results in disease epidemics of disastrous proportions. The introduction of potentially hazardous plant pathogens to a new cropping area generates risks in food production and likewise food security. Indeed, a large number of registered plant epidemics have reduced the production potential of various crops in the world throughout history (Strange and Scott, 2005).

Climatic changes are the major challenging issues faced globally in this century and also a key player in newly emerging phytopatholoical diseases. Continuous urbanization and industrialization comes with consequences faced from industrial development and the release of pollutants which ultimately results to shift or changes in temperature, rainfall pattern and concentration of carbondioxide (CO_2) in the atmosphere amongst others (Mahato, 2014). The major concern centers on the biotic and abiotic factors as they inter-play to affect the productivity of plants within the cultivation and growth period. The accumulation of greenhouse gases alone in the atmosphere affects humans, plants and animals in general. The gases in the atmosphere traps reflected radiation to warm the earth surface and results to several negative consequences which could include global fluctuation in temperature and rainfall patterns, drought, introduction of new or emerging phytopathogens, modification of vector behavioral patterns in disease management and control etc. However, human activities are widely attributed in increasing global climate changes that directly influences the ecosystem (Ahanger *et al.,* 2013).

Several approaches have been reported in the management of climatic changes which includes amongst others: the growing of heat resistant species, drought resistant species, breeding of genetically modified crops, disease resistant plants etc. There are increasing emphases on breeding crop varieties with durable resistance to major phytopathogens but these can take a long period of trials as repeated experimentation is required under different testing conditions (Angus and Fenwick 2008). Despite these, arable crops have relatively high level of flexibility to avoid or overcome any new disease problems that arises compared to systems such as orchards and forests (Shaw and Osborne

***Corresponding Author:** Labaran H.B.
Department of Biological Sciences, Rabiu Musa Kwankwaso College of Advanced and Remedial Studies, Tudun Wada, Kano State

2011). Diseases a biotic factor, is one of the main production constraints for farmers which requires consideration for control using different range of methods such as cultural practices, more resistant varieties and crop protection products. However, farmers and agrochemical companies face challenges of knowing emerging diseases in the future as resulted from shift in biodiversity of the phytopathogens meaning that fewer approved chemical control options and resistance to available pesticides might be a greater problem (Cools and Fraaije, 2008).

Climatic changes on the other hand pose greater and continuous challenges to plant pathologist, agronomist and agrochemical companies as intensive efforts to understanding factors that combines to favor plant disease occurrence such as: susceptible host, sufficient effective pathogen inoculum and suitable environmental conditions are constantly required. However, there are no direct control approaches over climatic changes when compared to the others, which are the main abiotic factors influencing arable crop disease. A holistic and integrated approach to understand changes in climatic factors which result to changes in the occurrence and severity of phytopathological diseases is of eminent necessity on a multidisciplinary scale. This paper aims to explore reported cases and influence of new emerging phytopathological diseases as relative to climatic changes.

Effects of climatic changes on plants and disease manifestation

Climatic changes can directly affect plant diseases by influencing spatial and temporal dispersal of propagules, synchrony of pathogen propagules with sensitive crop growth stages, frequency of suitable infection conditions (most fungal plant pathogens require wetness or high humidity for infection), host resistance (some resistance genes are temperature sensitive), speed of disease development (pathogen growth and for polycyclic pathogens number of disease cycles) and pathogen survival (frost periods, length of intercrop period, etc), which affects whether the disease is epidemic following importation of propagules from elsewhere, endemic or absent.

West *et al.,* 2011, reported climate change have indirect effect due to the inclusion in arable rotations of alternative crops maize and wheat in Europe that can act as hosts for certain pathogens, e.g. maize, a host to *Fusarium graminearum*, which also affects wheat. In addition to altered climate, Gregory *et al.,* 2009 reported changes in atmospheric gas concentrations encourage diseases since increasing ozone and CO_2 reduces resistance expression and also elevated CO_2 increase pathogen fecundity, leading to enhanced rates of pathogen evolution. In contrast, increased CO_2 was reported to increase pathogen latent periods (duration between infection and sporulation), which would reduce epidemic rates (Coakley *et al.,* 1999; Chakraborty and Datta 2003). Increased CO_2 was also reported to increase resistance of barley to *Blumeria graminis* (hordei) (Chakroborty *et al.,* 1998; Coakley *et al.,* 1999). Environment and particularly climate change, has been predicted to lead to an altered geographic distribution of both crop hosts and their pathogens as well as changes in host pathogen interactions and yield loss relationships (Coakley *et al.,* 1999). These environmental changes are likely to affect both polycyclic (pathogens with many cycles of infection per season) and monocyclic pathogens (pathogens with a single period of infection per cropping season). Increased inoculum production per infection, increased pathogen aggressiveness (or altered host resistance) and increased infection success of polycyclic pathogens is likely to produce an epidemic.

Climate change effects on crop diseases and particularly newly emerging infectious diseases (EIDs) should be put into context alongside a brief review of other factors that influence the emergence of new diseases. According to Anderson *et al.,* (2004), introduction is the most or second most important driver for emergence of new diseases in different pathogen groups (fungi, bacteria, virus and phytoplasmas). Weather conditions were found to be a major influencing factor for bacterial and fungal plant EIDs and although direct effects of climate were reported as relatively unimportant for plant EIDs that are caused by virus changes in vector populations were reported as the most important influence after pathogen introduction. Although, intensification, diversification, changed practices were identified as important driving factors of plant EIDs caused by fungi and viruses they were not mentioned as drivers of bacterial diseases. Anderson *et al.,* (2004) introduced the term 'pathogen pollution' to describe the anthropogenic movement of pathogens resulting in pathogen crossing a boundary that previously provided geographical or ecological separation. As a result, there may be heightened impact of introduced pathogens on naive susceptible host populations. Given the predicted continued increase in global air travel and trade volume, the number of introduced emerging diseases is also likely to increase. Harvell *et al.,* (2002) predicted an increase in the number of invasive pathogens. Brown and Hovmøller (2002) described instances where introduction of infected plant material (followed by local dispersal of spores) and long-distance airborne dispersal of spores had spread diseases to new continents.

Temperature changes and emerging plant diseases manifestation

Plants and phytopathogens require certain minimum temperature for their optimum growth and continuous development. As some survive better in higher temperature others prefer cooler temperature for their survival and general biological cycle. Changes in climatic temperature alter the chain of events in disease cycles which include: survival, dispersal, penetration, development and reproduction rate for many pathogens

(Tanmoy Das *et al.,* 2016). The optimal temperature for development and reproduction of phytopathogens varies significantly amongst groups; for viruses between 20 and 25ºC, bacteria from 25 to 30ºC, fungi between 15 and 35ºC (Postic *et al.,* 2011).

Tanmoy Das *et al.,* (2016) reported increasing temperature values, enhances spore germination of rust fungus *Puccinia substriata* and *Cercospora beticol* a leaf spot of sugar beet increased with annual mean temperature increase of 0.8 - 1°C in southern Germany. Generally, high moisture and temperature favors initial disease development as well as germination and proliferation of fungal spores of diverse pathogens (Agrios, 2005). Conidia of powdery mildew have the ability to germinate even at 0% relative humidity (Yarwood, 1978; Tanmoy Das *et al.,* 2016). Conidia of *Erisiphe cichoracearum* germinate at temperature from 7 to 32°C with a relative humidity of 60 to 80% (Khan and Khan, 1992; Tanmoy Das *et al.,* 2016) and spores of *Erysiphe necator* germinate at temperatures from 6 to 23°C with relative humidity from 33 to 90 % (Bendek *et al.,* 2007; Tanmoy Das *et al.,* 2016). Moderate temperature is the best for fungal growth that cause plant disease. *Phytophthora infestans* late blight of potato and tomato infects and reproduces most successfully at high moisture when temperatures are between 7.2°C and 26.8°C. Infection of *Eucalyptus sp*. by *Phytophthora cinnamomi* due to increased soil temperature between 12-30°C (Tanmoy Das *et al.,* 2016).

Sclerotinia sclerotiorum is a common disease of sunflower, but also infect numerous plant species and caused significant loss in yield and quality of sunflower grains reported in Croatia by Postic *et al.,* (2011). The disease spread due to weather conditions which were wet and cold for that part of the year (Simic *et al.,* 2008). Temperature plays vital role for the occurrence of bacterial diseases such as *Ralstonia solanacearum, Acidovorax avenae* and *Burkholderia glumea*. Bacteria proliferate best in areas where temperature dependent diseases have not been previously observed (Tanmoy Das *et al.,* 2016). Even the incidence of virus and other vector borne diseases are altered.

Rising CO_2 levels and emerging plant diseases manifestation

There are relatively large numbers of studies on the beneficial effect of increased concentration of atmospheric CO_2 on plant growth (Ghini, *et al,* 2008). Higher concentrations of CO_2 in the atmosphere results in beneficial effects to plant growth, although they might vary amongst species. The same conclusions have been reached by several research studies using different crops, natural ecosystems and forest species. Enriched CO_2 concentration promotes changes in plant metabolism, growth and physiological processes (Ghini, *et al,* 2008). There is a significant increase in the photosynthetic rate and a decrease in the transpiration rate per unit leaf area, while total plant transpiration sometimes increases due to the larger leaf area (Ghini, *et al,* 2008). These alterations also include higher efficiency in the use of water and nitrogen by the plant.

Despite all evidences of the beneficial effects of CO_2 on the host plant, it is not well known if these effects will still take place in the presence of biotic stress (pathogens) or other limiting factors. The effects of increased CO_2 concentration are observed on the host plant, resulting from alterations in the host pathogen relationship. Manning & Tiedemann (1995) reported an upward trend in diseases pathology with higher concentration of CO_2 based on the plant responses to diseases covering the period of 1930 to 1993. Increased carbohydrate contents could stimulate the development of sugar-dependent pathogens, such as rusts and powdery mildews. Recent review on 26 diseases by Chakraborty & Pangga (2004) reached a conclusion that most of the studied disease increased in severity within enriched CO_2 environments. According to Braga *et al.,* (2006), the exposures to higher CO_2 change inducible defensive responses in plants against pathogens. Also, Pangga *et al.,* (2004) stress the importance of induced resistance studies, besides canopy size, in the evaluation of CO_2 effects. The impact of increased CO_2 concentrations can be observed in several stages of the pathogen-host relationship cycle. Jwa & Walling (2001) studied the effects of elevated CO_2 concentration on the development of root rot in tomato, caused by *Phytophthora parasitica*. They reported that the pathogen incidence in the roots was significantly lower for plants grown under 700 ppm than under 350 ppm CO_2, but *P. parasítica* hyphal growth rates in vitro were similar for both concentrations. These overall effects could be noticed, due to the increase in root biomass and water-use efficiency by diseased plants which can reduce losses of infected plants by drought (Ghini, *et al,* 2008).

Effect of moisture on emerging plant diseases manifestation

With increased temperature various models on climate change predict frequent and extreme rainfall events and higher atmospheric water vapour concentrations. These encourage the crops to produce healthier and larger canopies that retain moisture as leaf wetness and relative humidity for longer periods and results in condition conducive for pathogens and diseases such as late blights and vegetable root diseases including powdery mildews (Das *et al.,* 2016). High moisture favours foliar diseases and some soil borne pathogens such *Phytophthora, Pythium, R. solani* and *Sclerotium rolfsii*. Drought stress affects the incidence and severity of viruses such as maize dwarf mosaic virus (MDMV) and beet yellows virus (BYV) (Das *et al.,* 2016).

Climate change and effects on plant pathosystem

The classic disease cycle emphasizes the interactions between host plants, pathogens and environment (Pautasso *et al.,* 2012; Das *et al.,* 2016). Climate change is one influential factor in which the environment can move disease-suppressive to disease-conducive or vice versa in the long term (Baker *et al.,* 2000; Fuhrer 2003; Truscott and Gilligan 2003; Perkins *et al.,* 2011; Pautasso *et al.,* 2012). Therefore, these could be used as one of indicators of climatic changes over time (Logan *et al.,* 2003; Garrett *et al.,* 2009; Pautasso *et al.,* 2012). Plant physiology generally suffers under climate changes through a variety of mechanisms, from accelerated pathogen evolution and shorter incubation periods to enhanced abiotic stress due to mismatches between ecosystems, climatic changes and occurrence of extreme weather events (Chakraborty and Datta 2003; Ghini *et al.,* 2008; Chakraborty and Newton, 2011; Pautasso *et al.,* 2012). Current predictions are made exclusively on the assumptions that hosts and pathogens have fixed climatic preferences with ranging conditions for growth, reproduction, transmission and competition (Yang *et al.,* 2023). However, it has been documented that climatic preferences for hosts and pathogens can evolve in response to shifts in local climate regimes (Corredor and Saunders, 2020). For example, recent works in the wheat pathogen *Zymoseptoria tritici* reported by Francisco *et al.,* (2019) and potato pathogen *Phytophthora infestans* reported by Lehsten *et al.,* (2017) demonstrate that these pathogens are adapted quite well to any changes in climate and these adaptation is attributable to changes in their genomic structure and gene expression (Yang *et al.,* 2023).

Conclusions and Research gaps

Understanding the potential impacts of climate change on agriculture in terms of its effects on emerging disease, severity and incidence is an important issue. Climatic changes affect diseases, yield, quality and general productivity of plants. Our knowledge is limited on how multifactor climate changes may affect plant health especially at genetic level. The only prediction is that climatic changes alter rates of pathogen development, modify host resistance and lead to changes in the physiology of host pathogen interactions which influences the severity of plant diseases. Climate change can have positive, negative or neutral impact on plant pathosystem considering the specific nature of the interactions of host and pathogen.

Once new phytopathogen emerges, the biggest threat is their dispersion into new geographical areas or hosting plant. Introduction of new phytopathogens is a global threat especially today with increasing urbanization and industrialization involving mobility of people, plants, seeds, soil, raw food and continuous climatic fluctuations (Avila-Quezada *et al.,* 2018). The spread of the pathogens could also take place through short and long distance dispersion pathways mainly involving;

a. Short-distance dissemination: Human practices (i.e. grafting and pruning) and vectors (e.g. insects or humans).
b. Long-distance dissemination: Weather (e.g. wind, rain and climatic changes), animals (e.g. birds) and domestic and international trade (Avila-Quezada *et al.,* 2018).

For example, spores alone can undertake journeys ranging from a few meters to thousands of kilometers, over land, or through air or water. Additionally, hurricanes can rapidly spread spores long distance as was observed from the Southern hemisphere to the north (Avila-Quezada *et al.,* 2018) or even from a continent to another, subsequently leading to the establishment of invasive pathogens. Management strategies employed by countries to mitigate pathogen emergence include efforts of establishing regulatory measures and quarantine bodies to prevent, control and eradicate diseases caused by pathogens. Phytosanitary regulations are performed worldwide to prevent, combat, and eradicate pests affecting plants. These programs have generated successful results to stop the introduction of diseases from abroad. Despite similar programs and regulations, pathogens manage to arrive in new crop areas via vectors, humans, or environmental factors.

Conflict of Interest

None. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Sultan, Z. is the supervisor to the research student and contributed mainly by reviewing the paper while Labaran, H.B. is the student who wrote the paper completely.

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