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A Review on Outcome of Climate Change on Plant Diseases and their Management

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A B S T R A C T

In this evolving time, where industrialization has became the major outcome of science, the human being and its need have lead to severe alteration in the climate and this we call as climate change. This climate change directs to variation in concentration of carbon di oxide, water fall and enhancement in temperature etc. The transformation in the element of climate change has huge impact on the plant disease as the occurrence of the plant disease relies on host plant, pathogen and the environment. Climate change alters the morphology and physiology of plants which ultimately influence its interaction with the pathogen. Pathogen get altered sporulation pattern, multiplication and even each stage of their growth is influenced by changing climate. So this review focuses on detail aspect of climate change and its impact on plant disease and their management.

Introduction

In this era of modernization the most critical environmental challenge in whole world is climate change. In the atmosphere to warm the earth surface greenhouse gases like Methane (CH_4), nitrous oxide (N_2O), carbon dioxide (CO_2), Ozone (O_3) and hydro fluoro carbons (HFCs) traps reflected radiation (Mahato, 2014). The major reason in raising worldwide climate changes that straightly affect the ecology is anthropogenic activities (Pachauri and Reisinger, 2007 and Ahanger *et al.*, 2013). There are several factors behind alteration of climate (Pachauri and Reisinger, 2007 and Pachauri *et al.*, 2014) and three component of disease triangle that is host; pathogen and environment are influenced by these changes (Legreve and Duveiller, 2010). Throughout the world climate change is influencing plants in natural and agricultural ecosystems (Stern, 2007). Crops and their interaction with microbes are directly affected by climate change (Rosenzweig *et al.*, 2000). Severe plant disease epidemics could be caused by this changing weather conditions (Bosch *et al.*, 2007, Chakraborty, 2005) ultimately influencing the staple crop by risking food security (Anderson *et al.*, 2004) and by injuring amenity species could harm landscapes (Bergot *et al.*, 2004). Climate change also lead to variation in nature, occasion and occurrence of different diseases in horticultural crops. Enhancement in temperature, rising concentration of atmospheric CO_2, change in pattern of precipitation and incidence of severe weather affects crop growth and production (Ghini *et al.,* 2008; Chakraborty, 2011; Rosenzweig and Tubiello, 2007). Small life cycle pathogen reproduces in very high rates in the host and method of dispersal occurs speedily and quickly acclimatizes to changing climate (Coakley *et al.,* 1999). Plant disease interactions are affected by CO_2 concentration and increased temperature (Lopez *et al.*, 2012) and thus threat perception of *Phytophthora infestans* causing late blight of potato, sheath blight caused by *Rhizoctonia solani and* blast caused by *Magnaporthe grisea* is enhanced (Kobayashi *et al.*, 2006). Disease management strategies for sustainable food production should be according to change in climate. The level of carbon dioxide (CO_2) atmospheric concentration has risen considerably in comparison to previous six fifty thousand years (Siegenthaler *et al.*, 2005). Same pattern is examined in different greenhouse gases like nitrous oxide (N_2O) and methane (CH_4) etc. (IPCC, 2007, Spahni *et al.*, 2005). Resulting, varied alteration in the climate has been accounted. In the past 30 years 0.2°C per decade increment in the average global surface has been noticed (Hansen *et al.,* 2006). Changes in the water cycle have also been observed. The study of effect of nutrition, air humidity and wind on plant disease incidence was started at some stage in eighteenth century and the starting of the nineteenth century (Colhoun, 1973). The growth and multiplication of host and pathogen, spread of pathogen, their susceptibility, continued existence, activity along with interaction with host is influenced by environment. Morphological and physiological modification occurs due to disease which is itself a vibrant process in which is both host and pathogen environment (Gaumann, 1950). This secure relationship between the environment and diseases proposes that this change in climate may cause manipulation in the current phytosanitory picture. A proper study of climate change probable outcomes on plant diseases is necessary to take different adaptation methods, for the expansion of resistant cultivars and novel management techinques to stay away from more serious losses (Chakraborty and Pangga, 2004; Ghini, 2005). The nature of plant pathogens is ubiquitous in natural and the controlled schemes, thus its first to show the influence of climate change because of huge populations, reproduction easiness and dispersal, and narrow time among generations. Therefore, they form a basic assembly of biological displayer that needs to be studied for climate change impacts. The aim behind this review is to make understand and analyze the result of change in climate on the temporal and spatial allocation of plant diseases.

Climate change and plant pathosystem

A significant position is stood by plant diseases in agriculture (Agrios, 2005). The knowledge regarding the climate change on plant disease is still limited. The interactions between plant hosts, pathogens and environment could be elucidated by the effect of environment on the standard disease triangle which ultimately causes disease (Grulke, 2011). Disease-suppression to disease-conduction or vice versa could be caused by the long term environment variation coming under one of the incidents climate change (Fuhrer, 2003; Perkins *et al.*, 2011). This demonstrates that plant diseases may act as indicator of climate change (Garrett *et al.*, 2009). Under changing environmental conditions plant disease development long-standing datasets are uncommon (Scherm, 2004) however, if present it could display the key significance of environmental change for health of plant (Fabre *et al.*, 2011). Generally under changed climate the health of plant is expected to suffer via different mechanisms like enhanced evolution of pathogen and reduced incubation periods because of augmented abiotic stress as there exists no matching among ecosystems and their climate and the additional recurrent incidence of severe weather occasions (Sutherst *et al.*, 2011). For example, frequency of tree pathogens is supposed to be increased by drought mostly by not direct effects on host physiology (Desprez- Loustau *et al.*, 2006). Direct effects of dry conditions have also noticed on pathogens like invasive exotic species another instance is of *Heterobasidion irregulare* in central Italy, well adjusted for distribution in the Mediterranean climate as compare to the native *H. annosum* species (Garbelotto *et al.*, 2010). More ever, in insect-vectored diseases, warmer temperatures causes increase in number of generation of insect, which ultimately increases invasive pathogen transmission rates (Robinet *et al.*, 2011). Climate warming has been reported to be coupled with alteration in plant hosts for certain fungi (Gange *et al.*, 2011). Few regional penalties on plant health due to climate change have been already observed like *Phytophthora infestans* in Finland (Hannukkala *et al.*, 2007). It is anticipated that pathogens such as *Sclerotinia sclerotiorum, Verticillium longisporum and Alternaria brassicae*, and is supported by average warmer temperatures, particularly in long term. This was reported at Northern Germany, in oil rape (Siebold and von Tiedemann 2012).

Different elements of climate like moisture, carbon di oxide, temperature etc. has different effects on the plant disease. Let's discuss these effects in detail

Moisture influence and its plant disease

Due to rise in temperature, different models foretell events of frequent and extreme rainfall and higher atmospheric water vapor concentrations. This condition lead to good vegetative growth, canopy retaining high moisture and relative humidity thus creating a situation that is highly favorable also for causal organism and diseases like vegetable root diseases consisting powdery mildews and late blights (Coakley *et al.*, 1999). Presence of high moisture favors foliar diseases and few soil borne pathogens like *Pythium*, *R. solani*, *Phytophthora*, and *Sclerotium rolfsii*. Viral disease incidence and severity was influenced by drought stress *Beet yellows virus* (BYV) and *Maize dwarf mosaic virus* (MDMV) (Clover *et al.*, 1999, Olsen *et al.*, 1990,).

Effect of carbon dioxide on plant diseases

Rise in the CO_2 levels influences both the host and the pathogen in different ways. There are different symptoms depicting enhanced CO2 levels like increment in size of plant organs, leaf area, thickness of leaf, and leaves number, elevated total leaf area per plant, branches and stems with diameter increased (Pritchard *et al.*, 1999, Bowes, 1993). The incidence of powdery mildew, rust, *Stemphylium* blight, anthracnose diseases and *Alternaria* blight are favored by dense canopy. It has been also reported that fungal spore production is enhanced by higher CO_2 concentrations. Another report also states that due to rapidly increasing temperature and CO_2, origin of new races may also take place. This occur as evolutionary forces creates pressure on large population of pathogen improved by a blend of augmented fecundity and infection cycles beneath advantageous microclimate in bloated canopy (Chakraborty, 2013). Few counteract action could be observed of CO_2 effects on disease. Denser canopies due to high CO_2 concentrations and high humidity enhances growth rates of leaves and stems this condition ultimately favor pathogens. Higher CO_2 condition also lead to reduced decomposition of plants rates that increases the crop residue on which disease organisms can overwinter. Residue of crop causes enhanced inoculums level at the initial of the growing season eventually causing early and faster disease epidemic. This explains elevated CO_2 concentration could lead to positive or negative effects on plant diseases, but in maximum of the cases disease severity has been increased (Manning and Tiedmann, 1995).

Effect of rising temperatures on plant diseases

Alteration in the temperature may evolve development of diverse inactive pathogens, which would lead an epidemic. Temperature and precipitation change leads to change in which eventually may am eventually alters the stages of growth, rate of development, causal organism's pathogenicity and host plants physiology and resistance (Charkraborty and Datta, 2003). In incidence diseases caused by bacteria like *Acidovorax avenae*, *Burkholderia glumea and Ralstonia solanacearum* temperature play a significant role. So, bacteria could easily flourish in the places where incidence of diseases relying on temperature has not been observed earlier (Kudela, 2009).

Studies has explained that with rise in temperature susceptibility of wheat and oats towards rust disease get enhanced, excluding few forage species gaining resistant with rise in temperature against fungi (Coakley *et al.*, 1999). Increased temperature also induces reduction in the durability of resistance genes due to the evolution of pathogen races (Garrette, 2006). Variation in temperature influences the host resistance, by affecting heat induced susceptibility and temperature sensitive gene

Effect of climate change in microbial interactions

Carbon cycling and the functioning of various ecosystems are influenced due to augmented CO_2 concentration in the atmosphere. The major factors influencing communities of soil microbes are deposition level of Nitrogen, temperature and concentration of CO_2 (Garret *et al.*, 2006).

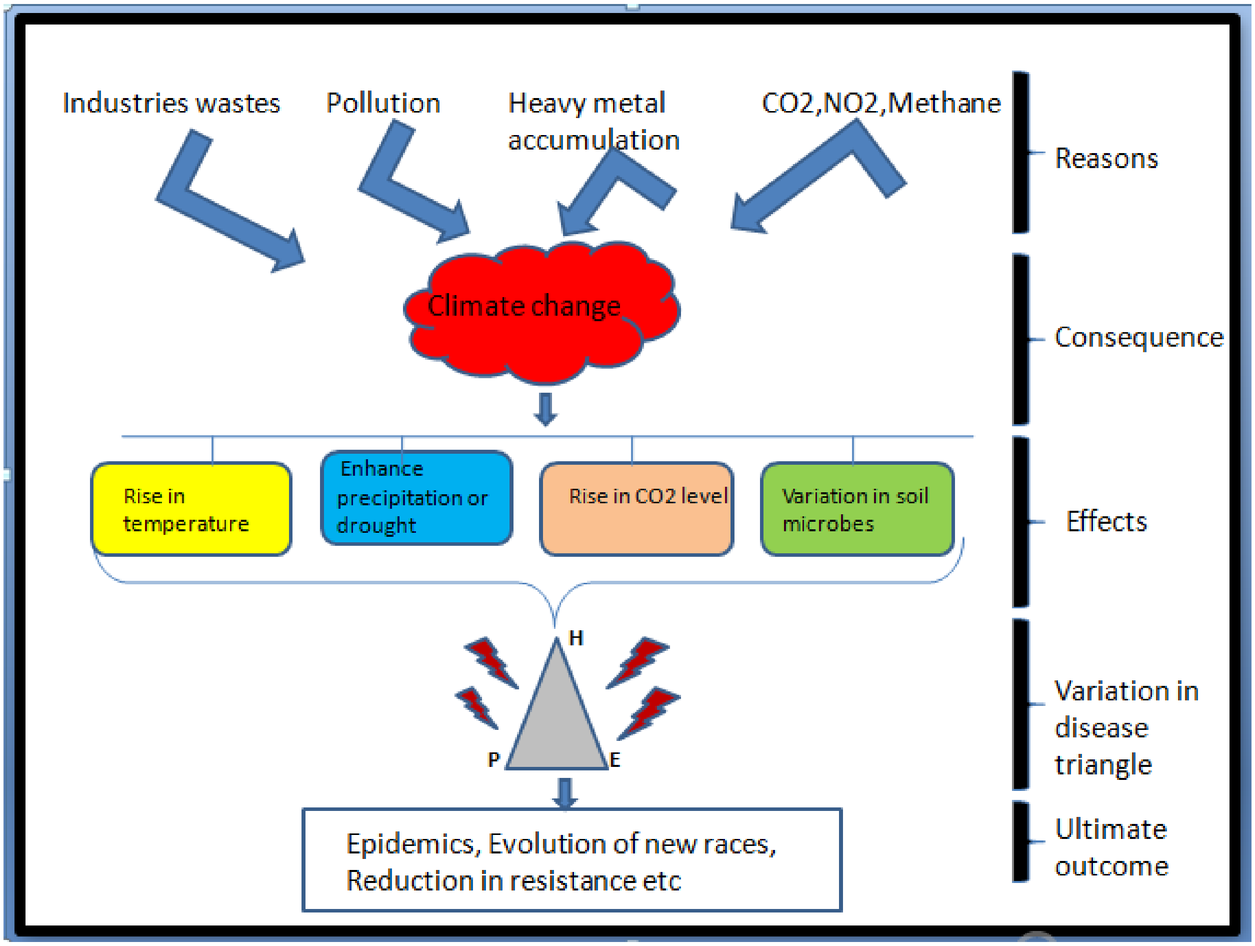
These short and extended-term alterations in the abiotic conditions influence growth of plant, their productivity and microbe's population surviving on. Plant growth and their ability to resist pathogens potential to attack the plants is influenced by modification in phyllosphere microflora (Fig. 1).

Effect of climate change on vector-borne diseases

The dispersal of plant viruses depends on the vectors and host. At local and regional level the threat of diseases of vector-borne and insect vector populations is dependent on the climatic requirements of disease vectors (Jones, 2009, Malmstrom *et al.*, 2011). Global warming as well affects the host primary infection, the dispersal of infection in the host and or the diffusion of the virus horizontally to a fresh host via specific vector. Climate change also has impact on plant phenology and physiology, which manipulates susceptibility against virus. Moreover effects on host physiology may influence the pleasant appearance of the host towards vectors and transmissible ability of virus. Due to climate change there are different effect on vector like manipulations on vector phenology, vector's over-wintering, density, migration and their stability.

Elevated CO_2 level have an effect on natural enemies of insect herbivores and through altering the dimension and composition of populationp of insects prey could indirectly influence the third trophic level. Thus, because of climate change any amend in plant population and population of insect vector could lead to dispersal of plant viruses (Canto *et al.*, 2008).

Fig.1 Climate change and its impacts. Here, H represents host, P stands for pathogen, E stands environment



Effect on fungicides

By altering stages of pathogen and their development rate, change in climate amend the physiology of host-pathogen interactions thus alter host resistance and also lead to shift in the host and pathogen geographical distribution (Coakley *et al.*, 1999). Under climate change situation few physiological transformation take place in host plants which may end result in increased resistance towards disease but this resistance via rapid disease cycles of pathogen could be easily break. The efficacy of fungicide and bactericide could be changed with increased CO_2, moisture, and temperature. Forecast made by climate change models, the incidents of recurrent rainfall result in washing of chemicals creating difficulty for farmers to sustain the residues of contact fungicides over the plants, causing increased recurrent applications. Physiological changes negatively affect systemic fungicides by slow uptake rates due to reduced stomatal opening, thicking of epicuticular waxes in crop plants grown under higher temperatures. Degradation of pesticides is also influenced due to enhanced temperature, thus altering plants physiology and morphology influencing their infiltration, translocation and mode of action (Elad and Pertot, 2014). According to Ghini (2008) enhanced canopy due to elevated CO_2 may influence the systemic fungicides infiltration, translocation and mode of action. Leaf surface characteristics also influences these chemicals like on retention of mancozeb on apple seedlings bean seedlings and knol-khol plants (Hunsche, 2006). He also reported strong negative correlation between fungicide retention and surface roughness and total cuticle wax. Thus he concluded that increased canopy size may have a negative impact on spray coverage and leading to dilution of active ingredients. As far as biological control is concerned less information is available.

Handling the consequences of climate change on plant diseases

These severe climatic conditions have created a huge pressure on growers as crops requirement for fungicide has increased. Fungicides higher spray treatments with higher application rates which eventually raise farmers cost of cultivation, charges for consumers and also develop resistance against fungicide (Juroszek and von Tiedemann, 2011). Including new cultivars and cultural practices for annual crops is quiet in comparison over perennials. To deal with this predicted climate change, first we should assess the worth of present chemical, biological and physical management methods and also acclimatizing novel tool and method (Coakley *et al.,* 1999). Millar *et al.,* (2007) reported that a single solution won't be sufficient to overcome this future climate change challenges but combination of different approaches adapted to different situations. Another outcome of climate warming is the invasive plant diseases spread in regions of naive host populations and this raises the need for greater than before monitoring and modelling (Loustau *et al.,* 2007; Moricca and Ragazzi, 2009). Without the help of the complete variety of recent and fresh executive approach only diversification may not be ample instances on the basis of climate change models, suggestion have been made that it would develop into essential to augment the treatments figure of fungicide against *Plasmopara viticola* in Northern Italy wine-manufacturing area of over the next decades (Francesca *et al.,* 2006). Moreover, increments of extension activities limiting the mistreatment and misuse of pesticides may also be well thought-out (Savary *et al.,* 2011). In the nearby future the present dependence on economically attractive management tactics will be challenged not only due to climate change, also by advances in society. For an instance improved environmental issue awareness of, e.g. the new pesticide regulations come into force in the European Community (Mills *et al.,* 2011; Erlacher and Wang, 2011). Employment of cultivar blending in fields and safeguarding of tree species thus maintaining diversity in forest are certain preventive measures which still make sense (Quijas *et al.,* 2010; Wiman, 2007; Juroszek and von Tiedemann, 2011, Finckh and Wolfe 1996, Pautasso *et al.,* 2005, Keesing *et al.,* 2010, Bodin, 2007, Zhu *et al.,* 2000, Garrett and Mundt, 1999). Further, innovative approaches would require, from assessment pest risks involving alteration in climate and economic considerations (Yemshanov *et al.,* 2009). In present time importance of novel agro-ecosystems has increased in this context whereas innovative approaches in plant disease management should be used (Fitt, 2011; Newton *et al.,* 2011).

Climate change operate at worlds wide due to short of epidemic processes reorganization at appropriate spatial and environmental scales the progress has been obstructed. In this area still limited research has been on climate change outcome on plant diseases beneath natural conditions on field or disease supervision in climate change. Changes in the rates of pathogen development, modification in resistance of host and alterations in the physiology of host - pathogen interaction eventually affecting plant diseases severity is only studied. Changing Climate may have constructive or destructive influence on pathosystem. The importance should be transferred to innovative adaptation and mitigation strategies from assessment of outcomes. Initially, assessment of the utility of present chemical, physical, and biological management strategies, involving disease-resistant cultivars, under climate change. Another is to involve situations of future climate in whole research meant at rising novel tools and plans. The analysis of disease risk may be relied on interactions of host–pathogen and researches on responses of host. The experiments should be made to explore the real inter relation between changing climate and microbes and to find out the best solution to adapt the current scenario and much more to come.

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