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Plant disease management strategies under changing climate scenario

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Abstract
Plant diseases are major problem of food production. Climate is dominating factor which influence the crop yield. Climate change directly affect rate of physiological process and biochemical process. Cliamte change result in increase in temperature, quantity and pattern of precipitation, increased CO_2 and ozone level, drought, etc. Any change in ecosystem can affect plant diseases, because plant disease is the result of interaction between a susceptible host, virulent pathogen and favourable environment. Increase in temperature and moisture can have some effect on fitness (no. of generation and sexual reproduction). Changes in temperature and precipitation alter the growth stage, development and pathogenicity of infectious agent. Persistence of fungicide on the plant surface depends on weather condition. Fungicides are wash out due to frequent rainfall and temperature. Changes in duration, frequency and intensity of rain events can alters the efficacy of chemicals. Model of plant disease have been developed to incorporate more sophisticated climate prediction.

Keywords: Scenario, climate, food production

Introduction
Plant diseases are major problem for food production including quality and safety of food. Climate is the most dominating factor influencing the suitability of a crop to a particular region. Crop mainly depends on climate. More than 50% of variation in the yield of a crop is due to climate differences. Climate change directly affects rate of physiological process and biochemical processes. Temperature, moisture, greenhouse gases are major variables of climate change. Climate change is affecting our agriculture due to 0.74^{o} C average global increase in temperature in the last 100 years and atmospheric CO_2 concentration increase from 280 ppm in 1750 to 400 ppm in 2013. Simultaneously, these changes will also affect the reproduction, spread and severity of many plant pathogens, thus posing a threat to our food security.
Climate change is also putting stem rust resistance due to Sr31 under threat of Ug99 race of stem rust caused by *Puccinia graminis f. sp. tritici*. Elevated temperature and CO_2 concentration are also posing higher threat perception of late blight (*Phytophthora infestans*) disease of potato and important diseases of rice, namely blast (*Pyricularia oryzae*) and sheath blight (*Rhizoctonia solani*). Changing disease scenario due to climate change has highlighted the need for future studies on such models which can predict the severity of important pathogens of major crops in real-field conditions. Simultaneously, disease management strategies should be reoriented in changing conditions with amalgamation of new strategies for sustainable food production.

Plant disease
A physiological disorder or structural abnormality that is deleterious to the plant or to any of its parts or product, that reduces their economics value. Disease is malfunctioning of host tissue which is due to interaction of susceptible host, virulent pathogen and favourable environmental condition called as disease triangle. Now a days time also added in disease development. Interaction of host, pathogen and environment at a specific time result in more severity of diseases.

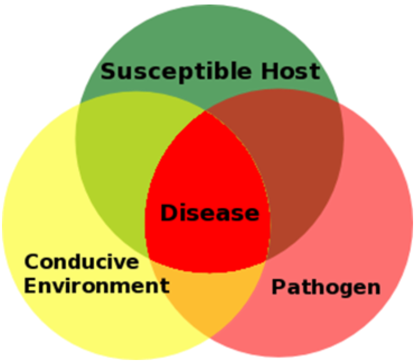

Fig 1.

Climate

Climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meterological variables in a given region over long period of time. Climate is average of weather and weather is a day to day condition of environment including temperature, humidity, precipitation, drought and greenhouse gases like carbon dioxide, methane, nitrous oxide, chloro fluro carbon.

Climate change

Climate change refers to a change in climate that is attributed directly or indirectly by human activity that alters the composition of the global atmospheric and climate variability observed over comparable time periods. Climate change refers to earth become warmer.

Global Warming

Global warming is the increase in the average measured temperature of the Earth's near-surface air and oceans since the mid-twentieth century. In general CO_2 in atmosphere is 345 ppm but due to emission of pollution and exhaust gases into atmosphere level of CO_2 increases which form blanket on the outer atmosphere. This causes entrapping of the reflected solar radiation from the earth surface. Due to this causing global warming, melting of ice cap and rise in ocean level.

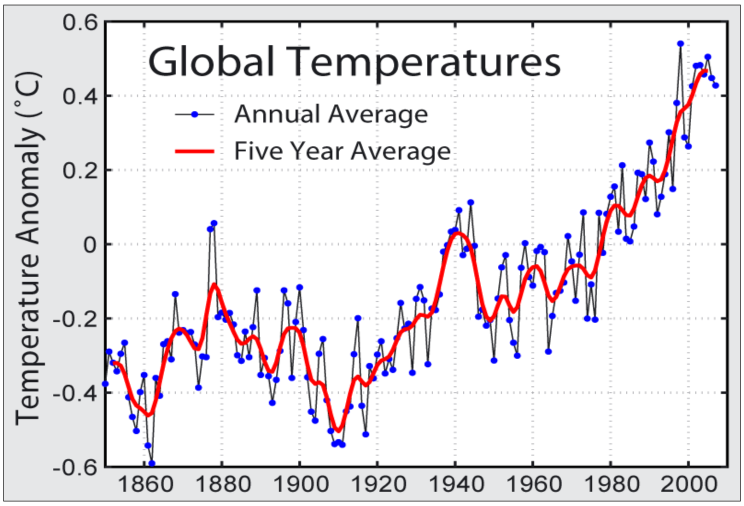

Fig 2.

How might the climate change

- Temperature increases- An increase in global mean annual temperatures of 1°C by 2025 and 3°C by the end of the next century.
- Sea Level Rises- Global mean sea level is estimated to have risen 10- 25 cm over the last 100 years. In the next 100 years the average sea level is projected to be about 50 cm higher than today
- Rainfall- Unexpected change in distribution. Change in intensity and frequency of rainfall climate is change.
- Increased Variability of Weather Events- Due to unavailability of moisture drought occurred.
- Carbon dioxide level increases- Concentrations of carbon dioxide, (the predominant greenhouse gas) have increased from 280 ppm to 383 ppm over the last 150 year (IPCC Report,2004).

Causes of Climate Change

Greenhouse Effect

The greenhouse effect is the process that warms the Earth surface. When sunlight reaches Earth surface some rays absorbed and warms the surface of earth and most of the rays reflected back to the atmosphere at a longer wavelength than sunlight in the form of infra red radiation. Some of these longer wavelength absorbed by the greenhouse gases. The absorption of this long wave radiant energy warms the atmosphere. The phenomenon of increase in ambient temperature due to formation of blanket of CO_2 is known as greenhouse effect.

In atmosphere content of carbon dioxide 55%, methane 25%, chloro fluro carbon 11%, nitrous oxide 4%.Greenhouse gases are emmited by various sector that is industrial processes 16.8%, transportation fuel 14%, landuse and biomass 10%, fossil fuel 11.3%,automobiles and deforestration and paddy cultivation.

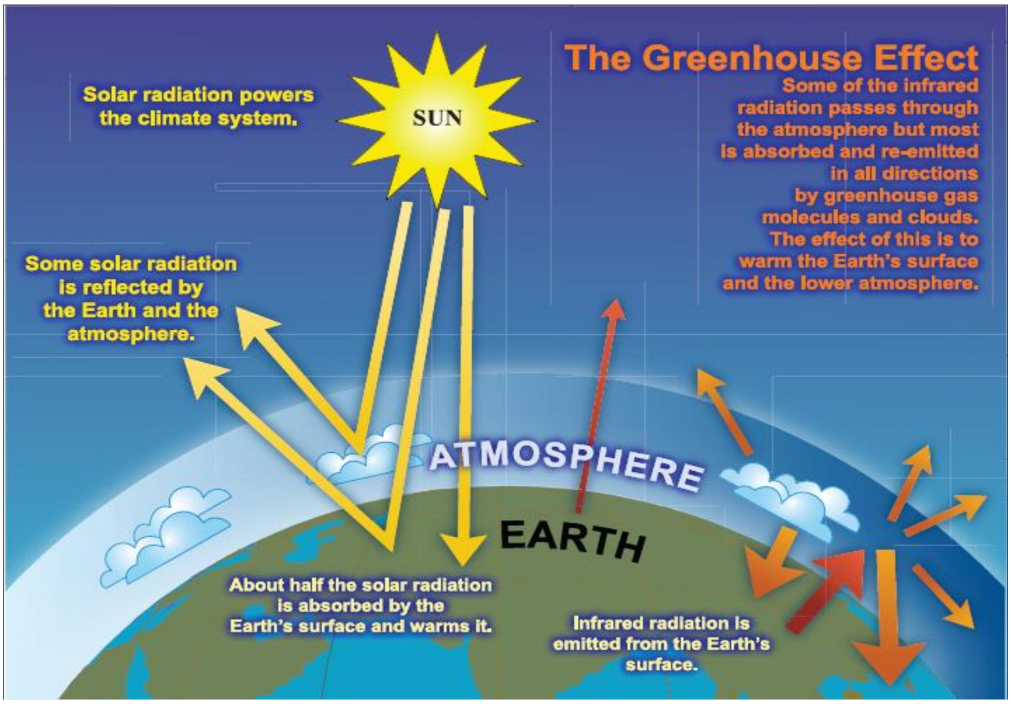

Fig 3.

Major Parameters of Climate Change

Effect of CO_2 Concentration

The effect of CO_2 concentration on plant disease can be positive or negative. An increase in CO_2 levels may encourage the production of plant biomass leads to increase in carbohydrates content which provide food for fungus automatically increase in disease severity. Concentration of carbohydrates in the host tissue promotes the development of biotrophic fungi such as rust fungus. Elevated CO_2 increases plant density will tend to increase leaf surface which regulate temperature and create microclimate around plant canopy also increase humidity thus increase infection by foliar pathogens like rust and powdery mildew fungi.

Plant grow in high carbon dioxide close their stomata and altered leaf chemistry because mostly bacterial plant pathogen can enter through natural opening, since stomata close leads to decrease incidence of diseases. Increase resistance to powdery mildew in barley. Higher CO_2 can increase the fertility of fungi, which may produce more spores. Altered the expression of soybean diseases, namely downy mildew (*Peronospora manshurica*), sudden death syndrome (*Fusarium virguliforme).*

Effect of Temperature

Changes in temperature alter the growth stage, development rate and pathogenicity of infectious agents. Pathogen required optimum temperature for growth, production of spores, germination of spores and mycelial growth. Increase in temperature reduce plant stress during the winter but increase stress on plant during summer. Wheat and oat become more susceptible to rust disease with increased temperature. Increase in temperature with sufficient soil moisture may increase in evapotranspiration resulting in humid microclimate in crop and lead to increase incidence of disease favoured under these conditions. Diseases such as common bunt (*Tilletia caries)* and Karnal bunt (*Tilletia indica*) in wheat can be of importance under changing climatic conditions in regions with low productivity if proper seed treatment is not followed in this crop.

Rust fungi adapt and benefit from higher temperature. Higher risk of dry root rot has been reported in *Fusarium* wilt chickpea-resistant varieties in those days when the temperature exceed 33^0c. Increase temperature and more frequent moisture increase incidence of dry root rot of chick pea (*Rhizoctonia bataticola*). Temperature sensitivity to resistance has reported for leaf rust *Puccinia recondita* and bacterial blight in rice.

Effect of Moisture

Moisture affect disease development by affecting the susceptibility of the host to infection and increase level of infection. Moisture can impact both host and pathogen. High moisture favours most of the foliar diseases and some soil borne pathogen such as Phytophthora, Pythium, Rhizoctonia etc. Some pathogens such as apple scab, late blight and several vegetable rot pathogens are more likely to infect plants with increased moisture content. Less rainfall and more severe summer incidence of different canker disease increases. Relative humidity critical for spore germination and development of storage rot. Moisture favours development of leaf and fruit disease caused by fungi and bacteria. Other pathogens like the powdery mildew species tend to thrive under conditions with lower moisture. In areas where moisture is decreasing due to climate change, fusarium wilt, dry root rot etc. become problematic for the cool season pulses.

Drought stress has been found to affect the incidence and severity of viruses such as Maize dwarf mosaic virus and Beet yellows virus. More frequent and extreme precipitation events that are predicted by some climate change models could result in longer periods with favourable pathogen environments. Host crops with canopy size limited by lack of moisture might no longer be so limited and may produce canopies that hold moisture in the form of leaf wetness or high-canopy relative humidity for longer periods, thus increasing the risk from pathogen infection.

Impact on disease management

Host management

Host resistance change because of changes in host morphology, physiology, nutrients and water. Cultivar resistance to pathogens may become more effective because of increased static and dynamic defences from changes in physiology, nutritional status, and water availability.

Durability of resistance may be threatened, however, if the number of infection cycles within a growing season increases because of one or more of the following factors: increased fecundity, more pathogen generations per season, or a more suitable microclimate for disease development. This may lead to more rapid evolution of aggressive pathogen races.

Browder and Eversmayer reported that wheat *Puccinia recondite* host pathogen gene pair related to resistance to different temperature ranges pairing produces low infectious rate. High CO_2 concentration in wheat had an average 14% reduction in nitrogen concentration in its shoot tissue that was associated with decrease susceptibility to powdery mildew. Lignification of cell walls increased in forage species at higher temperature to enhance resistance to fungal pathogen.

Chemical control

Climate change affect the efficacy of crop protection. fungicide and bactericide efficacy change with increase CO_2, moisture, temperature, more rainfall, difficult to keep residue of contact fungicide on crop. Changes in temperature and precipitation may alter the dynamics of fungicide residues on the crop foliage. Globally, climate change model project an increase in the frequency of intense rainfall events, which could result in increased fungicide wash-off and reduced control.

Increase canopy coverage negatively affect spray coverage. Increase metabolic rate because of higher temperature result in faster uptake of fungicide. Increase thickness of epicuticular wax layer on leaves could result in slower and reduced uptake by host plant.

The interactions of precipitation frequency, intensity, and fungicide dynamics are complex, and for certain fungicides precipitation following application may result in enhanced disease control because of a redistribution of the active ingredient on the foliage. Neuhaus *et al*. applied simulated rain to potato foliage at two intensities and found that the higher rate significantly reduced the fungicide residue that could be measured with a chemical assay, but that there was no difference in disease between the two treatments when the leaves were challenged in a bioassay with *Phytophthora infestans.*

Microbial interaction

Changed microbial population in the phyllosphere and rhizosphere may influence plant disease through natural and augmented biological control agents. Climate change alter the composition and dynamics of microbial communities in aerial and soil environment sufficient to influence the health of plant organ. In wheat rise in temperature 17-22º c result in increase in aphid reproduction by 10% at the same level and predatory activity by lady bird beetle adult increase by 250%. Aphid damage was reduced further because of earlier maturity of the crop. A direct effect of elevated CO_2 is unlikely in the soil environment as the microflora there is regularly exposed to levels 10-15 times higher than atmospheric CO_2. Lower nitrogen status of plant tissue under increased CO_2 results in more mycorrhizal colonization, this improve plant health. Changes in temperature may have highly non linear effects on interaction of host, pathogen and biocontrol agent.

Quarantine and Exclusion

Management of climate change will put additional pressure on agencies responsible for exclusion as a plant disease control strategy. Use of Geographical Information Systems and climate matching tools may assist quarantine agencies in determining the threat posed by a given pathogen under current and future climates.

Effect of climate change on vector borne diseases

Plant infecting viruses associated with their host and vector. Global warming influence the horizontal transmission of virus to new host by the vector. Effect of high temperature on the growth and reproduction of corn aphids are predicted to affect the population of this insect Climate change may affect both host plant and insect vector populations, there by affecting the spread of plant viruses. Global warming may influence the primary infection of the host, spread of infection within host and transmission of viruses to new host. Modification of the geographical range of the potential vector, vector phenology, overwintering, density and migration activity can follow. Elevated Co_2 level affect on natural enemies of insect herbivores, alter the size and composition of population of prey insects available to predators or by distrupting developmental synchrony for parasitoids.

Climate change and India

India is the most affected country due to climate change. Temperature increase by 0.5 degree Celsius has lead to decrease of 0.45 tonnes of wheat per hectare and decrease of 25 to 30 per cent sugarcane yield per hect

There is a paradigm shift in nature, time and type of occurrence of viral and other diseases of various horticultural crops due to climate change.

There is a severe occurrence of Indian Cassava Mosaic Virus in Kerala due to shift in climate conditions and new report of African Cassava Mosaic Virus and Sri Lankan Cassava Mosaic Virus because of rise in temperature and carbon dioxide levels. IISR, 2009

International Agencies Working on Climate Change

- **IPCC** Intergovernmental Panel on Climate change, Geneva (1988)
- **UNFCC** United Nations Framework Convention on Climate Change, New York (1992)
- **WMO** World Meteorological Organization, Geneva (1950)
- **UNEP** United Nations Environment Programme, Kenya (1972)

Disease Management Strategies

Strategies may required adjustment under climate change such as delay planting or application of biological control. But if proper temperature and moisture are not available bioagents not reach population required for pathogen. Physiological changes in host plant may result in higher disease resistance under climate change scenario. Under elevated CO_2 conditions, mobilization of resources into host resistance through various mechanisms such as reduced stomata density, greater accumulation of carbohydrates in leaves, more waxes, extra layer of epidermal cells, increased fiber content.

Geographic Information System (GIS) is commonly used to evaluate and model the distribution of plant disease in relation to environmental factors.

Using the 'Rice FACE' facility in Shizukuishi in northern Japan, studied the effect of 200–280 ppm above-ambient CO_2 on rice blast and sheath blight disease over three seasons. To control CO_2 and response of future ecosystem to a higher CO_2 concentration maximize the beneficial effect and minimize adverse effect. This technique also used in soybean.

Need for different model to assess the potential of emerging pathogens for given crop production system.

Simulation model

Model extensively used to predict yield of various crop in different agroecological zones under climate change. In rice combine effect of temperature and elevated UV, blast disease. Increase temperature with increase blast and associated yield losses in subtropical rice production region (Japan). Increased CO_2 was not considered, nor were changes in precipitation as preliminary analyses had indicated that the combined model was insensitive to changes in rainfall.

Climate matching

Climate matching involves the calculation of a "match index" to quantify the similarity in climate between two or more locations. The match index is based on variables such as monthly minimum and maximum temperatures, precipitation, and evaporation.

To quantify similarities in climate between two locations and analyse of the problem of disease at matching locations useful for prediction to be made about future disease risk at the location. Booth *et al*. identify regions suitable for leaf blight on *Eucalyptus spp.* Climate matching may be used for climate change impact assessment by identifying those locations on the globe with a current climate that is most similar to the predicted future climate at the location of interest.

Empirical models

Four diseases of two major crops in China, wheat scab and rice blast were examined by analysis to determine how they have varied through time and weather. In a similar study, Jahn *et al*. utilized long-term plant disease monitoring records collected by the State Plant Protection Service in the former German Democratic Republic (GDR) to develop empirical climate-disease models for 1individual host-pathogen combinations. These models were then used with various climate change scenarios to predict possible changes in "infestation levels" in a future climate.

Population model

In Finland the two models were coupled and extended by including leaf area expansion of the crop as a function of thermal time; calculating radiation interception as a function of leaf area; transforming the intercepted radiation to tuber dry matter and simulating the effects of late blight on tuber dry matter through a reduction in green leaf area, assuming that disease reduced leaf area to zero within14 days after the predicted outbreak warmer climate. The results suggested that tuber yield could increase by 2 t ha¡1 per 1º±C warming in the absence of late blight. This potential yield gain was almost completely offset when late blight was considered.

Conclusion

Indian agriculture is likely to be suffer losses due to climate change. Climate change can have positive, negative or neutral impact on individual pathosystem because of interaction of host and pathogen. Climate change will increase some disease risks and decrease others. Impact on plant disease have largely been considered in small scale experiment. These needs research, funding, policy support Current strategies for management need to be maintained and improved, even if the climate did not change. Serious lack of knowledge of the effects of some important factor such as elevated CO_2. Impacts on plant disease have largely been considered in small scale experiment.

When climate change considerations are included, deficiencies arise because of a lack of detailed knowledge of epidemiology and the relevant meteorological variables needed to predict epidemics at this spatial scale. Ideally, the necessary epidemiological data would be gathered from long term field studies in facilities where more than one climate change variable can be examined. As for meteorological data, statistical downscaling of GCM output offers interesting opportunities for developing climate change predictions for small scale units such as farm.

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