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Climate change and changing scenario of plant diseases in semi arid tropics

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Introduction

Increasing climate variability with the change in climate is recognized unequivocally. With the changing climate patterns and cropping systems, host, pathogen and favourable environment interactions are leading to diseases epidemics in a range of crops. Three essential components are required simultaneously for a disease to occur: a virulent pathogen, a susceptible host and favourable environment and the effect over time of the evolutionary forces on living populations leading to new disease epidemics often referred as "disease tetrahedran". Even with minor deviations from the normal weather, the efficiency of applied inputs and food production is seriously impaired (Rotter *et al*., 1999). Agriculture production of rainfed regions, which constitute about 65% of the area under cultivation and account for about 40-45% of the total production in India, is expected to suffer severe as a result of climate change (Agarwal, 2003).

Temperature, moisture and greenhouse gases are the major variables of climate change. The most obvious effect of climate change is on the global mean temperature which is expected to rise between 0.9 and 3.5 ºC by the year 2100 (IPCC, 2007). Cold days and nights and frost have become less frequent over most land areas, whereas hot days and nights are becoming more frequent. Variability in rainfall pattern and intensity is expected to be high. Greenhouse gases (CO_2 and O_3) would result in increase in global precipitation of 2 ± 0.5ºC per 1ºC warming. Climate variability is adding a new dimension to managing plant diseases by altering the equilibrium of host-pathogen interactions resulting in either increased epidemic outbreaks or new pathogens surfacing as threats or less known pathogens causing severe yield losses. This paper discusses the climate variables and how they affect the plant diseases giving some examples.

Changing scenario of plant diseases and pathogens

Climate change may affect plant pathosystems at various levels viz. from genes to populations, from ecosystem to distributional ranges; from environmental conditions to host vigour/susceptibility; and from pathogen virulence to infection rates. In general, climate variability has shown positive and negative impacts on host-pathogen interactions. However, in general climatic changes could result in following changes in diseases/pathogens a) extension of geographical range; b) increased over-wintering and oversummering; c) changes in population growth rates; d) increased number of generations; (e) loss of resistance in cultivars containing temperature-sensitive genes (f) extension of crop development season; (g) changes in crop diseases synchrony; h) changes in inter-specific interactions etc.

Plant pathogens have varying ranges of temperature requirements that affect the various steps in disease infection cycles such as penetration, pathogen survival, dispersal, epidemic development, survival and sexual reproduction. Few studies have shown that wheat and oats become more susceptible to rust diseases with increased temperature (Coakley *et al.*, 1999). Increased temperature and more frequent moisture stress (Drought) is predicted to increase in many regions and is likely to influence plant disease epidemics. For example, dry root rot of chickpea (caused by *Rhizoctonia bataticola*) is becoming more severe in rainfed environments as the host plant is predisposed by moisture stress and higher temperatures during the flowering to pd filling stage (Pande *et al*., 2010). Weather and dry root rot disease data collected in India for one decade showed higher incidence of dry root rot in chickpea varieties that resist Fusarium wilt in years when temperatures exceed 33°C (Pande *et al.*, 2010; Sharma *et al*., 2010). On the contrary, cooler temperature and wetter conditions are associated with increased incidence of stem rot on soybean (*Sclerotinia sclerotiorum*); blights (*Ascochyta* spp.) in chickpea, lentil, pea; and anthracnose in chickpea and lentil (Pande *et al*. 2010, Panagga *et al.*, 2004). Many models that have been useful for forecasting plant disease epidemics are based on increases in pathogen growth and infection with in specified temperature.

Another climate variable, moisture can impact bothy host plants and pathogens in various ways. For example high moisture (rainfall) favors most of the foliar diseases and some soilborne pathogens such as *Phytophthora*, *Pythium*, *Rhizoctonia solani* and *Sclerotium rolfsii* etc. Forecast models for these pathogens are based on leaf wetbness and relative humidity and precipitation measurements. An outbreak of Phytophthora blight of pigeonpea (*Phythophthora drechsleri* f. sp. *cajani*) in Deccan Plateau of India is attributed to erratic and heavy rainfall (>300mm in 6-7 days) leading to temporary flooding (Sharma *et al*., 2006; Pande *et al*., 2011). Alternaria blight of pigeonpea is being seen more frequently in recent years in semi-arid tropic regions due to the untimely rainfall (Sharma and Pande, unpublished). However, in areas where moisture is decreasing due to climate change, Fusarium wilt, dry root rot etc. will become problematic for the cool season pulses.

Most of the available data clearly suggests that increased CO_2 would affect the physiology, morphology and biomass of crops (Challinor *et al.*, 2009). Elevated CO_2 and associated climate change have the potential to accelerate plant pathogen evolution, which may, in turn, affect virulence. Pathogens fecundity increased due to altered canopy environment and was attributed to the enhanced canopy growth that resulted in conducive microclimate for pathogen's multiplication (Pangga *et al*., 2004). Foliar diseases like Ascochyta blights, Stemphylium blights and Botrytis gray mold can become a serious threat in pulses under the higher canopy density. Increased CO_2 will lead to less decomposition of crop residues and as a result soil borne pathogens would multiply faster on the crop residues.

Disease management strategies

Since regional impacts of climate change on plant diseases will be more, disease management strategies will require adjustments. Although physiological changes in host plants may result in higher disease resistance under climate change scenarios, the durability of resistance may be threatened and may lead to more rapid evolution of aggressive pathogen races (Hibberd *et al*., 1996). The population dynamics of beneficial microorganisms such as rhizobia, biocontrol agents and mycorrhizal fungi may get affected due to increased temperature, moisture and CO_2. Smith and Read (1997) suggested that arbuscular mycorrhizal fungi can modulate plant responses to elevated CO_2 by increasing resistance/tolerance of plants against an array of environmental stresses. Under elevated CO_2 conditions, mobilization of resources into host resistance through various mechanisms such as reduced stomata density and conductance (Hibberd *et al*., 1996); greater accumulation of carbohydrates in leaves; more waxes, extra layers of epidermal cells and increased fiber content and increased biosynthesis of phenols (Hartley *et al*., 2000), increased tannin content (Parsons *et al*., 2003) have been reported. The efficacy of fungicides may change with changes in climate variables. For example more frequent rainfall events could make it difficult for farmers to use the fungicides on plants leading to more frequent applications.

In addition to refinement in the existing management practices, there is a need for simulation models to assess the potential of emerging pathogens for a given crop production system and also shift in pathogen populations/fitness that may demand modifications in current production systems. Forecasting models which allows investigating multiple scenarios and interactions simultaneously will become most important for disease prediction, impact assessment and application of disease management measures. Many weather driven epidemiological models have been developed and used to predict plant disease epidemics under variable climate (Serge *et al*, 2011). Most forecasting models are meant for tactical and strategic decisions (Garret *et al.*, 2010). Another modeling is ecological niche modeling or species distribution models to anticipate the potential geographical range (Serge *et al.*, 2011). Recently, Geographic information system (GIS) is commonly used to evaluate and model the spatial distribution of plant disease in relation to environmental factors. Using GIS, Phytophthora blight of pigeonpea was monitored in the major pigeonpea growing areas in India indicating that Phytophthora blight occurs on improved as well as local cultivars of pigeonpea irrespective of soil types and cropping systems (Pande *et al*., 2010).

Conclusion

Regional impacts of climate change on plant disease management strategies need a relook using forecasting models and biotechnological approaches in understanding the emerging scenario of host pathogen interactions. Epidemiological knowledge, combined with biophysical and socio-economical understanding are required to deploy resistances and achieve sustainable disease management. There is a need for a greater understanding of the effect of climate variables on the efficacy of synthetic fungicides, their persistence in the environment, and development of resistance in pathogens populations to the fungicides. Recently, national and international net work is also actively anticipating and responding to biological complexity in the effects of climate change on agriculture and crop diseases (Serge et al., 2011). The primary benefit of such studies to growers will be their ability to control the diseases that become severe as result of climate change, select varieties that are less vulnerable for diseases, and reduce fungicide application. The information will be useful to the crop growers, scientists and extension agencies, NGOs, research planners, and administrators.

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