Impacts of Climate Change on Rainfed Crop Diseases: Current Status and Future Research Needs

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ABSTRACT

Weather-host-pathogen interactions over time have been a cause of concern as they hinder the efforts to ensure food security especially in developing and under-developed nations. Climate variability and climate change add a new dimension to this existing problem of managing crop diseases by altering the equilibrium of host-pathogen interactions resulting in either increased epidemic outbreaks or new pathogens emerging as threats or hither to less known pathogens causing sever yield losses. Detailed research is lacking in this domain to develop adaptation and mitigation strategies for sustained food security. Preliminary findings suggest that crops and pathogens respond differentially to altered weather patterns coupled with GHG emissions. These interactions could be either positive or negative. In this paper, an attempt has been made to assess the impacts of climate change on rainfed crop diseases and efforts needed for developing adaptation strategies.

INTRODUCTION

Climate change predictions point to a warmer world with in the next 50 years, a trend that is increasingly being supported by ‘ground-truth’. Climate change threatens to increase crop losses, increase in the number of people facing malnutrition, and may change the development patterns of animal diseases and plant pests. 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, varies a great deal from year to year. Therefore in order to sustain and enhance the production of the rainfed crops of SAT, it will be necessary to use the knowledge of climate variability to tailor of innovative cropping patterns and the disease management practices for each of the agroclimatic zones. It is well established that temperature, moisture and greenhouse gases are the major elements of climate change. Current estimates of changes in climate indicate an increase in global mean annual temperatures of 1ºC by 2025 and 3ºC by the 2100. Variability in rainfall pattern and intensity is expected to be high. Overall, changes in these elements will result in i) warmer and more frequent hot days and nights ii) erratic rainfall distribution pattern leading to droughts or high precipitation and iii) drying of semi-arid tropics (SAT) in Asia and Africa.

Effect of climate change on rainfed crop diseases

The climate variability and climate change has shown both positive and negative impacts on host-pathogen interactions. In the tropics and sub-tropics, with prevailing high temperatures, crops are already growing at a threshold. Under elevated CO_2 levels, the morpho-physiology of the crop plants is significantly influenced. Most of the available data clearly suggests that atmospheric CO_2 enrichment asserts its greatest positive influence on infected as opposed to healthy plants. This influence in turn will modulate the balance of co-evolution between the host and the pathogen as well as pathogen and its natural enemies. Elevated CO_2

and other factors of climate change have the potential to accelerate plant pathogen evolution, which may, in turn, affect virulence. Chakraborty and Datta (2003) reported loss of aggressiveness of *Colletotrichum gloeosporioides* on *Stylosanthes scabra* over 25 infection cycles under elevated CO_2 conditions. On the contrary, pathogen fecundity increased due to altered canopy environment. The reason attributed was to the enhanced canopy growth that resulted in conducive microclimate for pathogen's multiplication. McElrone *et al*. (2005) found that exponential growth rates of *Phyllosticta minima* were 17% greater under elevated CO_2. Lake and Wade (2009) have shown that *Erysiphe cichoracearum* aggressiveness increased under elevated CO_2, together with changes in the leaf epidermal characteristics of the model plant Arabidopsis thaliana. Recent surveys conducted and reports from SAT regions indicated that dry root rot (*Rhizoctonia bataticola*) in chickpea and charcoal rot (*Macrophomina phaseolina*) in sorghum increased many folds in last 2-3 years due to prolonged moisture stress. Preliminary analysis of weather indicated that outbreak of Phytophthora blight of pigeonpea (*Phythophthora drechsleri* f. sp. *cajani*) in SAT regions in last 5 years may be attributed to high intermittent rain (>350mm in 6-7 days) in July-August (Pande and Sharma 2009).

Climate change and changing scenario of pathogens

Climate change may affect plant pathosystems at various levels viz. from genes to populations and from ecosystem to distributional ranges; from environmental conditions to host vigour to susceptibility; and from pathogen virulence to infection rates. Climate change is likely to have a profound effect on geographical distribution of host and pathogens, changes in the physiology of host-pathogen interactions, changes in the rate of development of the pathogens e.g. increased oversummering and overwintering of pathogens, increased transmission and dispersal of pathogens and emergence of new diseases. Similarly, prolonged moisture may create a new scenario of potential diseases in SAT crops, such as anthracnose, collar rot, wet root rot, and stunt diseases in chickpea; to Phytophthora blight, Alternaria blight in pigeonpea, leaf spots and rusts in groundnut , blast and rust in pearl millet, leaf blight and grain mold complex in sorghum. Efforts are underway across laboratories to forecast the changing scenarios of pathogens and diseases of SAT crops under variable climatic conditions through simulation modeling and targeted surveys. Studies are also being initiated to understand behavior of the vectors of pathogens from the point of view epidemic development as well as biosecurity.

Development of adaptation strategies

Climate change is likely to have a profound effect on host plant interaction and is a challenge to the long-term sustainability of crop production. Regional impacts of climate change on plant diseases will be more hence; disease management strategy will require adjustments under climate change. Under elevated CO_2 conditions, mobilization of resources into host resistance through various mechanisms such as reduced stomatal density and conductance (Hibberd *et al*., 1996a, 1996b); greater accumulation of carbohydrates in leaves; more waxes, extra layers of epidermal cells and increased fibre content (Owensby, 1994); production of papillae and accumulation of silicon at penetration sites (Hibberd *et al*., 1996a); greater number of mesophyll cells (Bowes, 1993); and increased biosynthesis of phenolics (Hartley *et al*., 2000), increased tannin content (Parsons *et al*., 2003) have been reported. Malmstrom and Field (1997) reported that CO_2 enrichment in oats may reduce losses of infected plants to drought and may enable yellow dwarf diseased plants to compete better with healthy neighbors. On the contrary, in tomato, the yields were at par (Jwa and Walling, 2001). Similarly, Tiedemann and Firsching (2000) reported yield enhancement in spring wheat infected with rust incubated under elevated CO_2 and ozone conditions. Reduced incidence of Potato virus Y on tobacco (Matros *et al*., 2006), enhanced glyocellins (phytoalexins) after elicitation with ß-glucan in soybeans against stem canker (Braga *et al*., 2006) and reduced leafspot in stiff goldenrod due to reduced leaf nitrogen content that imparted resistance (Strengbom and Reich, 2006). However, no such research effort has been reported on the crop and diseases of the SAT environment.

Alterations in sowing dates may become less reliable. Resistance to pathogens will become more important because of static and dynamic defenses from changes in physiology, nutritional status and water availability. Durability of resistance may be threatened and may lead to more rapid evolution of aggressive pathogen races thus identification of new sources of resistance are of utmost importance. There is a need to view biological control with respect to variation in environment. In addition to improved diagnostics, 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. In addition to adoption of improved cultivars, 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. Also, the new scientific tools such as molecular markers will be helpful in speeding the progress of crop improvement.

The plant-pathogen systems are influenced by the population dynamics of beneficial microorganisms such as rhizobia, biocontrol agents and arbuscular mycorrhizal fungi (AMF). Smith and Read (1997) suggested that AMFs can modulate plant responses to elevated CO_2 by increasing resistance/tolerance of plants against an array of environmental stresses. In a study conducted at the Swiss FACE facility near Zurich, root colonization by AMFs increased considerably in the forage crops viz. *Lolium perenne* and *Trifolium repens*, at elevated CO_2, with more intraradical hyphae, arbuscules and vesicles suggesting and increased protection against pathogens (Gamper et al., 2004). In preliminary studies, it was observed that fecundity of *Trichoderma* increased in populations exposed over generations to elevated CO_2 and temperature (S. Desai, personal communication). Similar studies on natural enemies will help to understand the disease development in populations in a holistic way and also develop suitable adaptation strategies.

CONCLUSION

In conclusion, climate change is now real, so there is a need of impact assessment and strategies to cope with vulnerabilities in agriculture sector. Research has started only recently to understand the impacts of climate change on plant – pathogens interactions. In view of variable responses in pathogen behavior to climate variability and climate change, it may be difficult to know the ultimate outcome for specific pathogen-host interactions. A process-based approach to quantify the impact on pathogen/disease cycle is potentially the most useful in defining the impact of elevated CO_2 on plant diseases. More research, especially under field conditions, will be needed to clarify the situation; and, of course, different results are likely to be observed for different pathogen-host associations. Therefore, 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. Innovative methods may have to be adopted to develop adaptation strategies to overcome the impacts due to climate change and climate variability so that the food and livelihood security of rainfed farmers can be ensured. Studies under Network Project on Climate Change of the Indian Council of Agricultural Research, are underway to understand the variability among major soil borne pathogens such as *Sclerotium rolfsii*, *Macrophomina phaseolina, Rhizoctonia solani, Botrytis ricini and Fusarium ricini* and biocontrol agents such as *Trichoderma, Bacillus and Pseudomonas* for developing projected disease epidemiology on major crops through simulation modeling under climate change scenario. Recently an international net work is also actively anticipating and responding to biological complexity in the effects of climate change on agriculture and crop diseases (Karen et al. 2009).

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