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Impact of climate change on plant diseases: An overview

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Water-limiting environments, pest and diseases, declining fertility, availability and degradation of the soil resource are among key constraints to increasing production and quality of food (Kumar, 2011). Climate change adds an extra layer of complexity to an already complex agro-ecological system. Climate change primarily mediates the influence of plant diseases to affect production, quality and safety of food. Mycotoxins and pesticide residues in food are among the top food safety concerns associated with a changing climate.

Plant diseases are major constraints to the production, quality and safety of important food stuffs. Pest and disease management played important role in doubling food production in the last 40 years, but plant pathogens still claim10-16 per cent of the global harvest. In addition to reducing yield, they are of particular concern because of their direct impacts on human and animal health (Bisht, 2011).

Climate change and global warming are the two momentous problems of the present world. The earth's climate has always changed in response to changes in the atmospheric and interacting factors but human activities are now increasingly influencing changes in global climate. Since 1750, global emissions of radioactively active gases, including CO_2, from industry has increased rapidly as a result of the use of carbon-based fuels. Over the last 100 years, the global mean temperature has increased by 0.74^{0}C and atmospheric CO_2 concentration has increased from 280 ppm in 1750 to 368 ppm. in year 2000. Temperature is projected to increase by 3.4^{0}C and CO_2 concentration to increase to 1250 ppm by 2095, accompanied by much greater variability in climate and more extreme weather related events (Garrett *et al*., 2006). Meeting this difficult challenge will be made even harder if global warming melts portions of the Himalayan glaciers to affect 25 per cent of world cereal production in Asia by influencing water availability and more frequent floods affecting lives and livelihoods. These changes is likely to result in change in cropping pattern which may have implications for food availability, directly or indirectly, through, consequent changes in pathogen and pest incidence and severity. Plant pests and diseases could potentially cause tremendous loss (up to 82%) in attainable yield in case of cotton and over 50 per cent for other major crops. Each year, an estimated 10-16 per cent of global harvest is lost to plant diseases. In financial terms, disease losses cost US $ 220 billion. There are additional post-harvest losses of 6–12 per cent; these are particularly high in developing tropical countries that lack infrastructure. Plant diseases can be far reaching and alter the course of society and political history as attested by the devastations from infamous 19th century Irish potato famine or the Bengal famine.

The effects of climate change on plant disease management may be less important than changes in land-use patterns, transgenic technologies, and availability of chemical pesticides. The effects of climate change may tend to be different for different pathosystems in different locations, so that generalization is a challenge. The direct effects of climate change on individual plants and plant communities may occur in the absence of pathogens, but may also bring about changes in plants that will affect their interactions with pathogens. Changes in plant architecture may affect microclimate and thus risks of infection. In general, increased plant density will tend to increase leaf surface wetness and leaf surface wetness duration, and so infection by foliar pathogens more likely. Elevated CO_2 levels tend to result in changed plant structure. At multiple scales, plant organs may increase in size: Increased leaf area, increased leaf thickness, higher numbers of leaves, higher total leaf area per plant, and stems and branches with greater diameter have been observed under elevated CO_2. Enhanced photosynthesis, increased water use efficiency, and reduced damage from ozone are also reported under elevated CO_2 (Garrett *et al*., 2006). Since many foliar pathogens benefit from denser plant growth and the resulting humid microclimate, there is the potential for these changes in plant architecture to increase infection rates (Coakley *et al.*, 1999). Also, different populations of the same species may differ in both their genetic structure and the extent to which climate change will push the species to its physiological limits. As a result of climate change, the abundance of particular species may change rapidly, as species may lose their ability to recover from other perturbations such as diseases, insect herbivores, and climatic extremes within a background of climate changes. Novel plant communities may result with the increased potential for new patterns of host-sharing by pathogens.

The range of many pathogens is limited by climatic requirements for overwintering or over summering of the pathogen or vector. For example, higher winter temperatures of -6^{0}C versus -10^{0}C increase survival or overwintering of rust fungi (*Puccinia graminis*) and increase subsequent disease on *Festuca* and *Lolium*. In the case of *Phytophthora infestans*, the introduction of multiple mating types, allowing sexual reproduction, increases the ability of the pathogen to overwinter. For pathogens subject to an allelopathic effect, or destabilizing density dependent reproduction at low population levels, release from overwintering restrictions may have a much stronger effect than expected. Temperature requirements for infection differ among pathogen species. For example, wheat rust fungi differ in their requirements from 2^0-15^{0}C for stripe rust, 10^0-30^{0}C for leaf rust, and 15^0-35^{0}C for stem rust. In view of the effect of changing climate, temperature is considered as the dominant climate factor in terms of direct effects through effects on overwintering and the potentially important combination of photoperiod and temperature. In many cases, temperature increases are predicted to lead to the geographic expansion of pathogen and vector distributions, bringing pathogens into contact with more potential hosts and providing new opportunities for pathogen hybridization. Increased transportation and human movement may act synergistically with temperature changes (Bale *et al*., 2002). Temperature governs the rate of reproduction for many pathogens; for example, spore germination of the rust fungus *Puccinia substriata* increases with increasing temperature over a range of temperatures, and the root rot pathogen *Monosporascus cannonballus* reproduces more quickly at higher temperatures. Under climate change, some pathogens (as in case of plants) may potentially be unable to migrate or adapt as rapidly as environmental conditions change. But most pathogens will have the advantage over plants because of their shorter generation times and, in many cases, the ability to move readily through wind dispersal. Disease management strategies may require adjustment under climate change. Strategies such as delaying planting to avoid a pathogen may become less reliable; and one of the major problems with applications of biological control for plant disease management in the field has been the vulnerability of bio-control agent populations to environmental variation. Simulation models are based on theoretical relationships and can be used to predict outcomes under a range of scenarios. Because climate change occurs slowly and variably, it is difficult to study its effects directly. Temporal variability in climate can be used to draw inference about the potential effects of climate change through the argument that temporary effects of a year with unusual climatic features are likely to represent the effects of longer-term changes in environmental extremes. Models of plant disease have now been developed by various workers to incorporate more sophisticated climate predictions from General Circulation Models.

In the population level, the adaptive potential of plant and pathogen populations may prove to be one of the most important predictors of the magnitude of climate change effects on plant disease, since, for many species; populations will not be able to migrate quickly enough to keep pace with climate change (Murty, 2011).

Future research strategy : Due to the complex interaction of climate impacts, combined with varying irrigation techniques, regional factors, and differences in crops, the detailed impacts of these factors need to be investigated further. Specific recommendations for further research include:

– Precision in climate change prediction with higher resolution on spatial and temporal scales;

– Linking of predictions with agricultural production systems to suggest suitable options for sustaining agricultural production;

– Preparation of a database on climate change impacts on agriculture and

– Development of models for pest /diseases population dynamics.

Conclusion : It is evident that the relationship between climate change and agriculture is still very much a matter of concern with many uncertainties. Predicted changes in average values of global climate variables (increased temperatures, altered precipitation patterns, increased concentrations of atmospheric CO_2) and changes in the frequency, duration, and degree of extremes (such as frost, heat, drought, hail, storms, floods) will affect agricultural crops, agro-ecosystems, and agricultural productivity.

Forecasts of regional climate changes are still not precise. Overall, shortage of water will be the predominant factor affecting plant growth. As higher temperatures are known to enhance plant development and especially the grain-filling duration of cereals, grain yield losses are possible in a warmer climate. On the other hand, elevated atmospheric CO_2 concentrations are known to stimulate photosynthesis and enhance growth and yield, leaf transpiration is reduced, resulting in improved water use efficiency. Elucidating the interactions between positive and negative effects of climate change is of crucial importance for any prediction of future crop yields. The prediction of the response of crops to climate on both seasonal and decadal timescales shows promise. The potential benefit of increasingly accurate prediction is clear for the season, the mobilization of resources; for the adaptive measures to minimize the adverse impacts of climate change.

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