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Impact of climate change on plant diseases and their management strategies

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Abstract
Climate change will cause alterations in the disease geographical and temporal distributions and consequently the control methods will have to be adapted to this new reality. The efficacy of current physical, chemical and biological control methods under changing climatic conditions and research concerning new tools and strategies (including plant breeding) for coping with the predicted changes will be of great strategic importance. Fungicides may continue to serve as common disease suppression agents, although alternative measures, such as cultural methods and biological control, should be developed. There are few discussions on how chemical control will be affected by climate change, despite the importance of this subject. Changes in temperature and precipitation can alter fungicide residue dynamics in the foliage, and the degradation of products can be modified. The persistence of plant protection chemicals in the phyllosphere is highly dependent on weather conditions. Changes in duration, intensity and frequency of precipitation events will affect the efficacy of chemical pesticides and how quickly the active molecules are washed away. Temperature can directly influence the degradation of chemicals and alter plant physiology and morphology, indirectly affecting the penetration, translocation, persistence and modes of action of many systemic fungicides (Coakley *et al*., 1999). Indigenous microbial communities play an important role in maintaining plant health. There is a need to promote these beneficial communities. Recent technological advances, such as metagenomic analyses will increase our understanding of microbial dynamics in soil and other environments and further advance the establishment of plant pathogen suppressive microbial populations.

Keywords: Climate Change, Plant Diseases, Management

Introduction

Human activities have made greater impact on climate and ecosystem that resulting increased temperature, changes in pattern and quantity of rainfall, increased CO_2 and ozone levels, drought etc. Pathogens have challenged farmers since the first crop plants were domesticated during the transition to agriculture that occurred globally between 2000 to 12,000 years BP (Balter M. 2007) [3]. Climate change is the biggest threat of the present century. It is already contributing to the death of nearly 400,000 people a year and costing the world more than US$ 1.2 trillion, thus wiping 1.6% annually from the global GDP. Throughout the 21st century, India is projected to experience warming above the global mean. A warming trend has been observed along the west coast, in central India, the interior peninsula and Northeast India. A single factor of climate change like temperature can have a catastrophic effect on crop yield. Temperature increases of 1°C, 2°C and 3°C in Punjab, would reduce the grain yield of rice by 5.4%, 7.4% and 25.1% respectively. Climate change is the result of the acceleration in the increase in temperature and CO_2 concentration over the last 100 years. Changes in the climate and ecosystem can affect plant disease because a plant disease is the result of interaction between a susceptible host plant, virulent pathogen, and the environment. The development of new crop species and agricultural practices led simultaneously to the emergence of new pathogens and to significant changes in pathogen populations that already existed on the wild ancestors of the cultivated crops. Human activities (agronomic practices, fungicide treatments, movement of plant material in the global market, etc.) and the presence of microbial antagonists to the pathogen may also play roles in the development of a disease. Because the environment significantly, directly or indirectly, influences plants, pathogens, and their antagonists, changes in environmental conditions are strongly associated with differences in the level of losses caused by a disease, and environmental changes are often implicated in the emergence of new diseases (Anderson *et al.,* 2004) [1]. For these reasons, the changes associated with global warming (increased temperatures, changes in the quantity and pattern of precipitation, increased CO_2 and ozone levels, drought, etc.) may affect the incidence and severity of plant disease and influence the further co-evolution of plants and their pathogens

(Eastburn *et al.,* 2011) [8]. Temperature affects the growth of the crop, host–pathogen interactions and will alter the susceptibility window. Temperature rise above normal and increased humidity will predispose the crop to severe brown rust (*P. recondita*) infection and abet facultative pathogens

Studies revealed the effects of climate change on plant pathogens, but have not been able to provide precise projections of future scenarios. There are enough data to indicate that climate change will affect pathogen development and survival rates, modify host susceptibility, and result in changes in the effects of diseases on crops (Harvell *et al.,* 2002) [9]. However, any attempt to generalize is a challenge because the effects of climate change will differ by pathosystem and geographical region. Not only optimal infection conditions but also host specificity and mechanisms of plant infection may be affected by changes in climate.

Effects of Climate Change on Growth and Development of Pathogens

Biology of a pathogen can be directly influenced by environmental factors. Due to increase in temperatures, many pathogens will spread into new geographical areas and they will come into contact with new plant hosts. Production and germination of propagules and pathogen growth rates are strongly dependent on temperature, relative humidity (RH), and leaf wetness. In general, prolonged periods of environmental conditions *viz.* temperature, precipitation, and humidity are close to the optimal for the development of a pathogen lead to more damaging epidemics. Pathogen survival in the absence of a host (overwintering and over summering) can be affected by temperature and RH. Moisture and temperature cannot be considered separately. Decreased levels of rainfall may lead to decreased incidence of downy mildew infections of grape. Although increased temperatures are generally associated with an increased risk of disease development for most pathosystems, in some cases decreased precipitation results in a decreased risk of disease (Desprez-Loustau *et al.,* 2007) [7]. Canopy density and structure can affect the temperature, moisture, and availability of ultraviolet (UV) light at an infection site. Increased plant and leaf densities tend to increase leaf wetness, thus promoting the development of pathogens that prefer humid conditions. Necrotrophs obtain nutrients from dead tissues and are only limitedly affected by the active metabolism of host plant cells. In contrast, biotrophs derive their nutrition from living cells and have deep and prolonged physiological interactions with their hosts. Therefore, environmental factors that cause or accelerate tissue death, such as high temperatures or ozone levels, may favor infection by necrotrophs. On the other hand, factors that affect plant growth, such as elevated levels of CO_2 or increased temperature or drought, may cause changes in the physiology of a host species that will deeply alter the colonization of host tissues by biotrophic pathogens. Epidemics involving polycyclic pathogens are strongly influenced by the number of generations of the pathogens within a particular time period. Temperature and moisture govern the rate of reproduction of many pathogens (Caffarra *et al.,* 2012) [4].

Effects of Climate Change on Host–Pathogen Interactions

Climate change may directly affect several aspects of the biology of host plants, including their phenology (including senescence), sugar and starch contents, nitrogen and phenolic contents, root and shoot biomass, number and size of leaves, amount and composition of wax on leaves, changes in stomatal densities, and conductance and root exudation. Any change in any of these areas may influence infection and colonization by pathogens. For example, after infection, plant water potentials and nutritional content may affect the rate of colonization of host tissues, the production of new inoculums, and the expression of symptoms in the host. In situations in which host defense reactions (nonspecific stress-induced responses) to very specific reactions based on the presence of individual genes in both the host and the pathogen, as in the gene-for-gene interaction are affected by climate change. Abiotic stress may induce the activation of defense pathways, which not only increase resistance but also increase the susceptibility of the plant to certain pathogens. Moisture and temperature can affect disease development by affecting the susceptibility of the host to infection and/or increasing the level of symptom expression. Drought may impair production of plant defense substances or growth, favoring the progress of the pathogen. Drought and temperature stress have been shown to negatively affect a plant's ability to respond to biotic stresses via changes in endogenous abscisic acid levels that affect defense responses involving salicylic acid, jasmonic acid, or ethylene (Asselbergh *et al.,* 2008) [2]. In some pathosystems, host-pathogen gene pairs that are related to resistance have been found to interact differently at different temperature ranges. Similar to temperature, both increased CO_2 and ozone concentrations may alter plant function but usually in opposite ways. In general, photosynthesis, leaf area, plant height, total biomass (shoot and root) and crop yield, sugar and starch content, water-use efficiency, growth, and yield are increased in the presence of higher levels of CO_2, but they are negatively affected by higher levels of ozone (Eastburn *et al.,* 2011) [8]. Fecundity of some pathogens may increase at elevated CO_2 concentrations (Chakraborty and Datta, 2003) [5], thereby accelerating the potential for accelerated pathogen evolution. Similarly, it is difficult to generalize the effects of elevated ozone levels on disease (Sandermann, 2000) [11]. Elevated ozone concentrations may change the structure and properties of leaf surfaces in ways that may affect the inoculation and infection process (Karnosky *et al.,* 2002). Ozone enhances senescence processes, may encourage necrosis, and seems to promote attacks on plants by necrotrophic fungi (Sandermann, 2000) [11].

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