CLIMATE CHANGE AND ITS IMPACT ON PLANT HEALTH: A PAKISTAN'S PROSPECTIVE

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A R T I C L E   I N F O

A B S T R A C T

Climate change is an expected phenomenon, however, its impact on life, environment and different sectors of economies such as agriculture could be unexpected. Agriculture sector is more prone to climate change both directly as well indirectly such as new emergence of pest and diseases in changing climate. Agriculturists through simulation crop modeling successfully forecast the impact of changing climate on different crops. Crop modeling by comparison with plant disease modeling is much simple as only plant and subsequent impact of environment on it is predicted. Forecasting plant disease is much more complex as it involves the pathogen, plant and environment. Plant disease forecasting in advance remains paradox due to cryptic and complex nature of plant diseases. It is paradox as some pathogens only grow well when temperature is high, and humidity is low while on other hand low temperature and high humidity is pre-requisite for most of pathogens. Therefore, an expected phenomenon climate change can unexpectedly lead to many unprecedented diseases in country like Pakistan which is considered as 7th most vulnerable country to climate change in world. The situation would be worst as on average 1.8 million automobiles are entering in Pakistani market which result more release of CO_2 and rise of temperature. It is a tailor-made situation for epidemics to occur as rise in temperature accelerate pathogen evolution and shorten the incubation time. China Pakistan Economic Corridor (CPEC) is an economic game changer but it could lead to entry of invasive pathogen species in Pakistan. Smog is another upcoming challenge which could also lead to many diseases especially viral diseases due more activity of vectors. Therefore, continuous climate and pest monitoring is needed to develop efficient disease warning system for growers and other agriculture related agencies to avoid future plant epidemics.

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INTRODUCTION

Among plant scientists, plant pathologists were earliest to realize the role of environment in disease development and its subsequent impact on host-microbe interaction. Therefore, there is conscious effort to make environment as part of core concept of disease triangle along susceptible host and virulent pathogen. Later, it was also found that disease would not occur if all these variables not act at the same time (Stevenson, 1960). Though, plant and animal pathology share lot of commonalities, but disease triangle concept is only workable in phyto-pathological studies because unlike animals and humans,

plants are sessile organisms and can't run away from dangers of surrounding environment. It is interesting to note that disease triangle is helpful to measure plant disease in quantitative terms. Sometimes like in case of most of viruses presence of susceptible host, virulent pathogen and conducive environment not ensure the disease. Rather, viruses mostly needed carrier which mostly an insect to reach the host. Therefore, disease triangle was also supposed to accommodate vector. Nevertheless, decisions such as which variety of crop to grow, when to sow, where to cultivate, how much fertilizer or water to be given etc. are made by humans which subsequently shape the patho-system. Latern on, to accommodate all these factors or concerns, a disease pyramid was favoured over disease triangle (Francl, 2001). Epidemiologists are successfully predicting future outcome of plant-microbe interaction on the basis of past observation and present pathological data along prevailing and expected environmental scenario. The other beneficiaries are plant disease management experts or farmers who successfully manipulated local environment to create unfavorable environment for pathogen growth, reproduction and dispersal (Agrios, 2005). Studying disease in context of pathogen, host genetics, environment, human practices is a routine exercise in plant pathology since ages, but the scope is very local and limited. Till 1990, plant pathologists never thought of linking disease with changes in climate. In recent time, climate changes massively disturb the human life but also environment, therefore, it become imperative to link plant diseases with changing climate (Campbell and Madden, 1990; Van Maanen and Xu, 2003). **Climate change and plant disease:** Climate is usually defined as an aggregate of weather prevailing over 30 years (Goosse et al., 2010). But unlike weather, climate take significant times to change therefore organisms buy enough time to cope with changing climate. But living species which failed to adjust with changing climate either face extinction or marginalization (Malcolm et al., 2006). Unfavorable weather can provide some room for living species to escape or tolerate as it is day to day affair but there is no rescue when climate become unfavorable for any species as it stretches over decades. Climate change is rule not an exception and data shows significant change of climate since inception of life on planet earth. But human activities such as burning of fossil fuels and automobile industry of last 150 years accelerated the pace of climate change. Release of greenhouse gases and

carbon dioxide (CO_2) are major players in recent climate change. Till 1950, atomospheric carbon never crossed 300 ppm line but currently it is more than 400 ppm. The recent surge in carbon level cause increase average temperature of earth to 1.1°C (NASA, 2018). This trend seems continue unless a collective effort was not made by human race. Climate change in recent past resulted into warming of oceans, shrinking of ice sheets, glaciers retreat, rise of sea level, ocean acidification, dryness etc. which disturb human life and economies directly or indirectly. But the most affected sector which hit by climate change is agriculture. Soils become drier and extra amount of water needed to irrigate them. Plants especially horticultural crops are under stress due to dryness and sporadic and unprecedented precipitations followed by floods and erosion (Calzadilla et al., 2013). Results of recent studies broke decades old myth that high amount of CO_2 is actually beneficial for plants but in fact it is found that high CO_2 level had no effect on plant growth. Conversely, increase temperature due to high amount of atmospheric CO_2 would have negative impact on plant growth (Zhu et al., 2016). Liu et al. (2016) found 1°C rise in global temperature decrease wheat yield upto 5%. The other worrisome area which makes plant scientists perplexed is unexpected behavior of insects and plant pathogens in relatively warmer weather due to climate change. There might be shift in host range due to accelerated pathogen evolution and short incubation period (Phillips et al., 2010). This would be a tailor-made situation for plant disease epidemics.

It is plausible to mention that since 1960's plant pathologists has idea about role of environment in disease and later generation of plant pathologists also realized the importance of human intervention (Plank, 1963). But to relate diseases with climate change is bit tricky and takes time to be accepted by pathology fraternity. Epidemiologists developed computer-based disease models for major crops and fruits trees which are helping growers, extension workers to assess severity of disease under prevailing environmental conditions. But unlike crop modeling, plant disease modeling is kind of double edged sword. Pathogens differ when it comes to environment. Few pathogens such as powdery mildews, *Colletotrichum, Xathomonas* sp., *Ralstonia* sp. need a period of dryness and high temperature to progress while downy mildews, *Phyophthora* sp., *Pseudomonas* sp., grow well at relative high humidity and cool weather. In crop modeling, it is comparatively easy as modeling people

only need to monitor crop and environment and forecast future outcome. Conversely, in plant disease modeling not only plant, environment but also pathogen is also monitored which could be mono or polycyclic. Practically, it become even more difficult to give a conclusive statement when two taxonomically and physiologically different organisms reacting with similar physical factors. In addition, pathogens also react with plant and soil microbiota which can behave differently under different environment. This complexity can lead to a total misinterpretation of future outcomes. Changing environment also influences the presence, survival, movement, reproduction of insects which are inevitable for viral diseases to occur (Karuppaiah and Sujayanad, 2012). In developed world where precision agriculture is practiced new approaches are adopted to minimize negative impacts of climate change. But under developed country like Pakistan whose economy is majorly is agri-based and also considered 7th most vulnerable country to climate change; a well-versed approach needed to avert future plant disease build up.

Climate change and upcoming plant disease scenario in Pakistan: All international organizations working on climate change are convinced that Pakistan would face worst effects of global climate change. Obviously, patho-system would also be affected by this climate change. There are signs which if rightly observed and interpreted help to gauge the situation. Tree decline and dieback is emerging problem in tree plantations in Pakistan. It started from guava and shisham decline in 90's and now similar phenomenon is observed in trees such as mango, citrus, loquat etc. Though, symptoms are more or less similar but reported causal organisms differ tremendously. It include pathogens such as *Fusarium oxysporum* and *Colletotrichum gloeosporioides* (Ansar et al., 1994), *Phytopthora cinnamoni*, *Ceratocystis fimbriata* (Masood et al., 2011), pathological complex include bacteria, fungi, mollicutes (Ali et al., 2014), *Lasiodiplodia theobromeae* (Naz, 2017) etc. This confusion exists because all authors more or less worked on etiology of disease but there is no concrete effort to co-relate occurrence tree disease with changing climate. When we looked at the number of automobiles sold in Pakistani market in same era. To our surprise, there is steep growth as only 24000 vehicles sold in 1995 which reached 0.89 million in 2007 and 2017 crossed figure of 1.8 million (PAMA, 2018). This unwarranted and unprecedented increase in automobile units has increase

carbon foot print in atmosphere. Tree being perennial plants suffered most by this micro-climate change. However, no interdisciplinary effort is made to tackle this menace of plant growth. Only sporadic, independent but inconclusive efforts were made by researchers. Bajwa et al. (2015) pointed out that rise in temperature and precipitation had profound impact on blue pine (*Pinus wallichiana*) in Murree forest area. An educated guess could be drawn that climate change made these perennials more vulnerable against pathogens against whom in past these plants showing resistance.

Plant pathologists in Pakistan needed to broaden their scope while diagnosing disease problem and suggesting its management in future. Climate change would play a pivotal role in shaping future patho-systems and must not be ignored. Especially when there is so much infrastructure development is going on under the umbrella of China Pakistan Economic Corridor (CPEC). Undoubtedly, CPEC would be a game changer not only in region but also in world trade but Pakistan need a realistic evaluation of CPEC impact on Pakistan's agriculture. There would be 3871 km new roads and 1529km new railway track on which annually 300-400 m ton/annum cargo will move across length and breadth of country (CPEC, 2018). It will bring prosperity but there is chance that it would also bring invasive pest from Africa to China and from Central Asia to Europe. Paini et al. (2016) while highlighting global threat of invasive species emphasized China and US pose greatest threat to rest of world when it comes to spread of invasive species Pakistan would be an ideal place for invasive pest and diseases due to tropical to sub-tropical weather and number of hosts to invade and overwinter. In past, banana cultivation jolted due to invasive Banana Bunchy Top Virus (BBTV) (Khalid et al., 1993). Pakistan needed to equip and train its quarantine department to avoid future epidemics. Pakistan's booming automobile industry is good news for growing economy, but it can lead to future mishap if not properly address. It is reported that there is 4°C increased of temperature in Indus delta at the end of this century which is considered as food basket of Pakistan (Rasul et al., 2012). Many believe that boom in automobile sector and loss of trees due to urbanization is actual reason of smog in Pakistan which not only threatening public health, road safety but also crop production.

Smog: A new player shaping plant health in Pakistan: Smog word is originated from two words smoke and fog. Smog formed due to release of gases in atmosphere especially under cooler weather. In simple words it is bad

side of industrialization, mechanization and urbanization. In recent years, Punjab province in Pakistan is badly under smog during winter months which paralyzed urban life as well life on roads. There are reports that smog effect crop production and there is 10-30% yield loses due to smog are estimated in industrial countries where it started in mid 40's. Relative yield losses in different states of India ranged from 30–42 % for wheat, 22–26 % for rice, 3–5 % for maize to 47–58 % for cotton *in vitro* conditions when exposed to ozone (Sinha et al., 2015). Plants under smog remain under stress due to unavailability of light. In addition, smog injured plants which created infection courts later invaded by insects and pathogens (Stark and Cobb, 1969). Nevertheless, it is reported by various authors that except honey bees and silkworms, there is more population and activity of insects especially aphids a known vector for plant viruses. This is reason why more viral diseases were reported in plants growing under smog (Alstad et al., 1982; Braun and Flückiger, 1985; Dohmen et al., 1984). By digging into literature, a hypothesis was built that there must be increase of new disease reports from Pakistan in last few years as more CO_2 added into air and more agriculture trade was occurred. To testify we underpin published data about new disease reports from Pakistan in last ten years.

Our overview of published data revealed that there were 23 new diseases were reported from Pakistan in span of last ten years. Out of 23 diseases 20 were fungal, 2 were viral while only 1 was caused by bacterium. It is interesting we couldn't find a single new disease report on nematode of same period in Pakistan. Out of 20 fungal diseases, 9 were caused by fungi belonging to *Alternaria* spp. Newly reported fungi not only causing pre-harvest but post-harvest diseases in field, horticultural and in plants of insignificant economic importance such as *Dracaena marginata, Yellow oleander, Chenopodium album, Calotropis gigantean, Rumex dentatus* and *Sonchus*

oleraceus (Figure 1a). However, these plants could serve as alternate host and post serious threat to crop production in future. It is recently reported that high incidence *Alternaria* spp. co-related with elevated levels of CO_2 and temperature (Siciliano et al., 2017). Two new viruses which were reported from Pakistan were Tomato leaf curl New Delhi virus on *Eclipta prostrate* (Tahir and Haider, 2005) and Tomato leaf curl Gujarat virus on cotton (Zaidi et al., 2015). These viruses were previously reported from India (Chakraborty et al., 2003; Hussain et al., 2004). Presence of these viruses shows the fragility of quarantine law and practices in Pakistan. The situation could be worst in CPEC scenario if quarantine laws will not be implemented with letter and spirit. Pathogens and hosts co-evolve together, therefore, resistance against local pathogens present in locally co-evolved plants. However, if plants are invaded by exotic pathogens then they have no innate defense to blunt pathogens ingresses which led into complete crop failure.

It is plausible to mention that only one bacterium *Pectobacterium atrosepticum* was reported from sunflower crop (Asad et al., 2017)*.* The overall picture emerged by unraveling of published data is that new diseases appear on every type of crops. The worrisome part it picks pace in 2015-17 where 11 new pathogen species have been reported in Pakistan by different authors. It must be kept in mind that this was time when Pakistan faced worst kind of smog and limited trade activity also started on CPEC routes (Figure 1b). Now, there is dire need of a collective and inter-disciplinary approach to tackle upcoming issue of plant health in country. An out of box strategy based on sharing of data and expertise can only helpful to meet the mammoth challenge. Otherwise, plant epidemics could pose a serious threat to national food security which will ultimately affect the fragile social fabric of country.
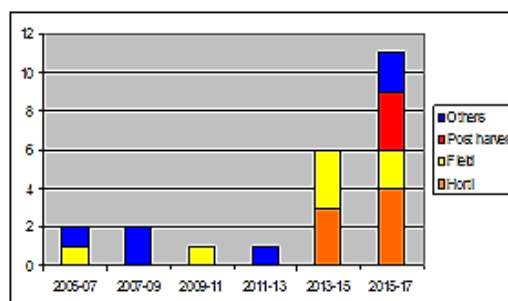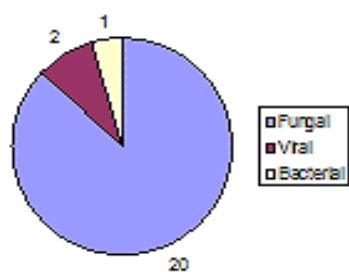

Figure1. Overview of new diseases reported from Pakistan (2005-17) a) Total number of different kind of pathogens b) Yearly data of new diseases on different type of crops.

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