S. S. Sreenivas, International Journal of Advances in Agricultural Science & Technology,
Vol.9 Issue.9, September-2022, pg. 1-4

ISSN: 2348-1358
Impact Factor: 6.901
NAAS Rating: 3.77

Impact of Climate Change on Crop-Pathogen Interaction: A Review

S. S. Sreenivas
Chief Technical Officer-Crop Protection (Rtd)
ICAR-Central Tobacco Research Institute, Rajahmundry 533 105, AP, India
vas_sss@yahoo.co.in

DOI: 10.47856/ijaast.2022.v09i09.001

***Abstract:** Crop response to climatic variation is critical criterion not only in yield and productivity but also, its interaction with pathogens. Disease triangle happens under a favourable weather, virulent pathogen and a susceptible host. Climate change influences both host plant and pathogens leading to altered interaction and disease cycle. Carbon dioxide is a major contributor in the green house gas phenomenon. The consequent influence of GHG effect on temperature due to warming and erratic seasonal weather has an impact on both plant and pathogen development. Physiological changes in plants impact pathogenicity and disease development. Altered crop physiology under climate change is more susceptible to biotic stress. Hence, it is essential to understand impact of climate change on host plants to know the disease dynamics.*

***Keywords:** Climate change; temperature; water; CO_2; host response; pests and diseases*

Introduction

Climate change over past few years is towards global warming and resultant increase in the average atmospheric temperature. Green House Gases like carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons *etc.*, trap solar radiation resulting in increased atmospheric temperature. Specifically, the CO_2 level is the main cause of climate change because of its major contribution. Etheridge (1996)[1] reported CO_2 concentration of 400ppm threshold from 285 ppm at the start of 19th century with the trend being attributed to anthropogenic reasons[2]. Global climatic variations influence agriculture tremendously and needs adaptation strategies in farming to enhance agricultural production[3]. Climate changes are likely to cause rise in sea levels, frequent weather extremities and changes in precipitation. Agricultural production and productivity are totally dependent on climatic situations[4,5]. Global grain demand will double by 2050 as a result of population growth[6]. Climate change has a great impact on host-pathogen interaction and possible alteration in disease dynamics[7,8]. Estimates suggest at least 10% loss in food production due to diseases[9]. The paper is a review on critical impact of climate change on crop plants and dynamics of disease development.

Plant response to changes in water regime

Crop plants show strong response to climate in its growth and establishment along with other abiotic conditions. Changes in water regime influence crop yields while, it may enhance plant-pathogen interaction due to increased canopy, total plant biomass and change in micro-climate by favouring certain foliar fungal groups[10,11]. Intensification of agriculture to augment production of a particular crop may lead to increase in pathogen/vector population leading to major epidemics[12]. Crops under abiotic stress especially drought are vulnerable to infection by pests and pathogens due to complex interactions. Water stress on crop vs pathogen interaction is complicated with lower infection rates under conditions of low RH by several foliar pathogens and plants exhibiting fewer symptoms when subjected to drought stress due to poor root development[11,13,14]. Water-stress may alter resistance mechanism and results in development of disease when crop gets exposed to drought [15]. Drought and temperature stress influence levels of endogenous abscisic acid that affect defence responses involving salicylic acid, jasmonic acid, or ethylene[16]. Increased rain-fall pattern is likely to change the crop-diversity and shifting to new varieties resulting in a new disease cycle. Very few reports are available on the potential influence of climate change on the severity of

ISSN: 2348-1358
Impact Factor: 6.901
NAAS Rating: 3.77

forest diseases. A few predicted devastating diseases reported are epidemics of *Phytophthora cinnamomi* in oak in France[17], root rot in woody plants[18], and diseases caused by pathogens that infect stress-predisposed trees[19].

Plant response to changes in temperature

Higher temperatures are critical for crop growth may bring changes in soil-ecosystem, alter soil-microbial dynamics and responsible for changed plant-pathogen interaction. Temperature and moisture stress together play vital role in increasing the vulnerability of crops to diseases due to reduced resistance gene expression and of new race development in pathogens[20-23]. High temperatures are lethal to crops leading to stress related out comes like high transpiration losses and poor productivity. Mean seasonal temperature can reduce the duration of many crops and hence reduce the yield and quality. Impact of rise in temperature is more pronounced in crops already in physiological maximum[2]. In some pathosystems, resistance gene action may respond differentially to temperature fluctuations, decreasing the resistance to invading fungal diseases[24]. Climate change affects defence reaction of host plants to very specific reactions in case of gene-for-gene interaction[25] and due to failure of temperature sensitive genes[26]. Higher temperatures may add to the lignifications in crop plants as a defence mechanism to pathogen entry[27].Higher temperatures result in extended growing seasons and allow longer life cycles of insect vectors spreading virus diseases. Temperature rise increases stomatal activity[28] facilitating virus multiplication and vector acquisition process. At higher temperatures virus spread is more by the breakdown of hyper sensitive gene response[29] and some mutations in virus coat protein gene and result in altered virulence[30]. Effectiveness of viral resistance is reduced at low temperatures in case of gene silencing mechanism[31]. However, increment to a certain level is deleterious to certain viruses[32]. Kido et al. (2008)[33] reported that low temperature leads to expression of symptoms while high temperature leads to latent infection in their studies on melon necrotic spot virus. Spread of vector-borne diseases depends on changed vector activity due to alterations in host physiology and morphology. Increased temperature decreases the effectiveness of single dominant gene resistances making virus resistant cultivars susceptible[34,35]. Altered temperature and moisture may favour weed species formerly unable to establish may become reservoirs in spreading pathogens to crop plants[36,37].

Plant response to changes in CO_2 concentration in atmosphere

Elevated CO_2 concentration results in increased net photosynthetic rates[38] and may also alter stomatal opening and thereby reduce transpiration rate[39]. Higher CO_2 levels increase canopy due to more photosynthetic activity in C_3 crops and likely, to offer ground for more disease through multiple life cycles of pathogen[40-44]. Runion et al. (2010)[45] concluded that elevated CO_2 increases host resistance to *Cronartium quercuum* f.sp. *fusiforme* and *Fusarium circinatum* two pathogens of devastating diseases in forest plants. Silicon known to increase disease resistance in rice plants[46] will be effected by CO_2 concentration and increases susceptibility[42].Crops with higher carbohydrate concentration due to increased CO_2 concentration may play host to diseases like rusts[47] and are likely to influence endogenous metabolites. Mulherin et al. (2000)[48] reported that elevated CO_2 alters endogenous foliar salicylic acid levels and affects plant response to TMV inoculation. Elevated CO_2 effects photosynthesis and secondary metabolites which may influence vector-borne virus epidemics indirectly due to changed vector behaviour[49]. Increased biomass poses the risk of infection due to increased leaf surface wetness duration and regulated temperature conditions for infection by foliar pathogens[11,50-53].

Conclusion

Hosts plants, vectors and pathogens are influenced by climate change effects like, changed rainfall patterns, increased temperature, seasonal droughts and elevated CO_2 concentration in the atmosphere. These changes are likely to alter plant-pathogen interaction which may have positive, negative, or neutral impact on individual pathosystems depending on the phenology and physiological changes in the host plants. Crops being cultivated under environmental conditions which are not optimum may suffer phenologically and physiologically resulting in more susceptibility to biotic stress. Hence, the complex nature of host-pathogen interaction necessitates a clear understanding of host response to climate change in sustaining the crop yields.

ISSN: 2348-1358
Impact Factor: 6.901
NAAS Rating: 3.77

References

[1] Etheridge D.M., L.P. Steele, R.L. Langenfelds, R.J. Francey, J.M. Barnola, V.I. Morgan. 1996. Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn. J Geophys Res. 101:4115–4128.
[2] IPCC, 2007, An assessment of Intergovernmental Panel on climate change. Climate change synthesis report, Cambridge University Press, Cambridge, U.K. p-73
[3] Fraser, E.D.G., Termansen, M., Sun, N., Guan, D., Simelton, E., Dodds, P., Feng, K. and Yu, Y. 2008. Quantifying socioeconomic characteristics of drought sensitive regions: evidence from Chinese provincial agricultural data. *Comptes Rendus Geosciences*. 340:679-688.
[4] Srinivasarao Ch, Gopinath K A, Prasad J VN S, Prasanna K and Singh A K, 2016, Climate resilient villages for sustainable food security in tropical India: Concept, process, technologies,institutions, and impacts. Advances in Agronomy. 140(3): 101-214
[5] Bal S K and Minhas P S, 2017, Atmospheric Stressors: Challenges and Coping Strategies. In: P.S. Minhas et al (ed) Abiotic Stress Management for Resilient Agriculture, Springers Nature Singapore Pte. Ltd., pp.9-50
[6] Tilman D, Cassman KG,Matson PA, Naylor R, Polasky S, 2002, Agricultural sustainability and intensive production practices. Nature 418, 671–7
[7] Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Otsfeld, and M. D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. *Science* 296: 2158–2162.
[8] Nargis Nazir, Sheikh Bilal, K.A. Bhat, T.A. Shah1, Z.A. Badri, F.A. Bhat, T.A. Wani, M.N. Mugal, Shugufta Parveen and Stanzin Dorjey. Effect of Climate Change on Plant Diseases. *Int.J.Curr.Microbiol.App.Sci* (2018) *7*(6): 250-256
[9] Strange, R.N., Scott, P.R. Plant disease: A threat to global food security. *Annual Review* of *Phytopathology 2005;*43: 83-116.
[10] Dalla Pria, M, Christiano R C S, Furtado E L, Amorim L and Bergamin Filho A, 2006, Effect of temperature and leaf wetness duration on infection of sweet oranges by Asiatic citrus canker. Plant Pathol. 55: 657-663
[11] Huber L and Gillespie T J, 1992, Modelling leaf wetness in relation to plant disease epidemiology. Annu. Rev. Phytopathol. 30:553–577
[12] Morales, F.J., and P.K. Anderson. 2001. The emergence and dissemination of whitefly-transmitted geminiviruses in Latin America. Archives of Virology.146:415–41.
[13] Huisman OC, 1982, Interrelations of root growth dynamics to epidemiology of root-invading fungi. Annu. Rev. Phytopathol. 20:303–327
[14] Pennypacker, B. W., K. T. Leath, and R. R. Hill Jr., 1991, Impact of drought stress on the expression of resistance to *Verticillium albo-atrum*in alfalfa. Phytopathology 81:1014–1024
[15] Newton A C, Young I M, 1996, Temporary partial breakdown of MLO-resistance in spring barley by the sudden relief of soil water stress. *Plant Pathol*. 45: 973–77
[16] Asselbergh, B., D. De Vleesschauwer, and M. Hofte. 2008. Global switches and fine tuning ABA modulates plant pathogen defense. *Mol. Plant-Microbe Interact*. 21:709–719.
[17] Bergot M, Cloppet E, Pérarnaud V, Déqué M, Marçais B and Desprez-Loustau M L, 2004, Simulation of potential range expansion of oak disease caused by *Phytophthora cinnamomi* under climate change. Glob. Change Biol. 10:1539–1552
[18] Jung T, 2009, Beech decline in Central Europe driven by the interaction between *Phytophthora* infections and climatic extremes. For. Pathol. 39:73–94
[19] Sturrock R N, Frankel S J, Brown A V, Hennon P E, Kliejunas J T, Lewis K J, Worrall J J and Woods A J, 2011, Climate change and forest diseases. *Plant Pathol.* 60:133–149
[20] Boyer J S, 1995, Biochemical and biophysical aspects of water deficits and the predisposition to disease. Annu Rev Phytopathol. 33:251–274
[21] McElrone A J, Sherald J. L and Forseth I N, 2001, Effects of water stress on symptomatology and growth of *Parthenocissus quinquefolia* infected by *Xylella fastidiosa.* Plant Dis. 85:1160–1164
[22] Garrett K A, Dendy S P, Frank E E, Rouse M N, and Travers S E, 2006, Climate change effects on plant disease: Genomes to ecosystems. Annu. Rev. Phytopathol. 44:489–509
[23] Caffarra A, Rinaldi M, Eccel E, Rossi V and Pertot I, 2012, Modeling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. Agric. Ecosyst. Environ. 148:89–101
[24] Browder L E and Eversmeyer M G, 1986, Interactions of temperature and time with some *Pucciniarecondita: Triticum* corresponding gene pairs. Phytopathology. 76:1286–1288
[25] Gessler C and Pertot I, 2012, Vf scab resistance of *Malus.* Tree Struct. Funct. 26:95–108
[26] Colhoun J (1973) Effects of environmental factors on plant disease. Annu. Rev. Phytopathol. 11:343–364
[27] Strange R N (1993) Plant disease control: towards environmentally acceptable methods. London: Chapman and Hall

ISSN: 2348-1358
Impact Factor: 6.901
NAAS Rating: 3.77

[28] Ainsworth E A, Rogers A, 2007, The response of photosynthesis and stomatal conductance to rising CO2:
[29] molecular mechanisms and environmental interactions. Plant Cell and Environment. 30:258–70.
[30] Samuel G, 1931, Some experiments on inoculating methods with plant viruses and on local lesions. Annals of Applied Biology.18:495–506
[31] Yoon JY, Chung B N and Choi S C, 2011, High-temperature mediated spontaneous mutations in the coat protein of cucumber mosaic virus in Nicotiana tabacacum. Archives of Virology.156:2173–80
[32] Chellappan P, Vanitharani R, Ogbe F and Fauquet C M, 2005, Effect of temperature on geminivirus-induced RNA silencing in plants. Plant Physiology.138:1828–41
[33] Frost R.R and Harrison B D, 1967,Comparative effects of temperature on the multiplication in tobacco leaves of two tobacco rattle viruses. Journal of General Virology. 1:455–64
[34] Kido K, Tanaka C, Mochizuki K, Kubota K and Tsuda S, 2008, High temperatures activate local virus multiplication and cell-to-cell movement of melon necrotic spot virus but restrict
[35] Fraser R.S.S, Laughlin S A R, 1982, Effects of temperature on the Tm-1 gene for resistance to tobacco mosaic virus in tomato. Physiological Plant Pathology. 20:109–17.
[36] Canto T, Palukaitis P, 2002, A novel N gene-associated, temperature-independent resistance to the movement of Tobacco mosaic virus vectors, neutralized by a Cucumber mosaic virus RNA1 transgene. Journal of Virology.76:12908–12916
[37] Latham L J and Jones R A C,1997, Occurrence of tomato spotted wilt tospovirus in weeds, native flora and horticultural crops. Australian Journal of Agricultural Research.48:359–69
[38] Jones R A C, 2009, Plant virus emergence and evolution: origins, new encounter scenarios, factors driving emergence, effects of changing world conditions, and prospects for control. Virus Research. 141:113–30
[39] Cure J D and Acock B, 1986, Crop response to carbon dioxide doubling. A literature suvey. Agriculture and Forest meteorology. 38: 127-145
[40] Kimball B A, 1983, Carbon dioxide and agricultural yield: an assemblage and analysis of 430 prior observations. Agronomy Journal. 75:779–88
[41] Amthor J S, 2001, Effects of atmospheric CO2 concentration on wheat yield: review of results from experiments using various approaches to control CO2 concentration. Field Crops Res. 73: 1-34.
[42] Fuhrer J, 2003, Agro-ecosystem responses to combinations of elevated CO2, ozone and global climate change. Agric. syst. Environ. 97: 1-20
[43] Kobayashi T, Ishiguro K, Nakajima T, Kim H Y, Okada M and Kobayashi K ,2006, Effects of elevated atmospheric CO_2 concentration on the infection of rice blast and sheath blight. Phytopathology. 96:425–431
[44] Stern N (2007) The economics of climate change: the Stern review. Cambridge, UK: Cambridge University Press. p. 712
[45] Ziska L H, Runion G B, 2007, Future weed, pest, and disease problems for plants. In: Newton PCD, Carran RA, Edwards GR, Niklaus PA, eds. Agro-ecosystems in a Changing Climate. Boca Raton, FL, USA: CRC Press, 261–87
[46] Runion et al., 2010, concluded that elevated CO_2 increases host resistance to *Cronartium quercuum* f.sp. *fusiforme* and *Fusarium circinatum* two pathogens devastating diseases in forest plants
[47] Kim S G, Kim K W. Park E W and Choi D, 2002, Silicon-induced cell wall fortification of rice leaves: A possible cellular mechanism of enhanced host resistance to blast. Phytopathology. 92:1095–1103
[48] Manning W J and von Tiedemann A, 1995, Climate change: potential effects of increased atmospheric CO_2, ozone and ultra violet – B (UV-B) radiation on plant on plant diseases. *Environmental Pollution*. 88: 219-245
[49] Mulherin K M, Karowe D N and Enyedi A J, 2000, Effects of elevated carbon dioxide on plant-pathogen interactions. In plant Biology 2000. Plant Biology Meeting. Symposium Elevated CO2. Abstract number 368. San Diego, Ca. USA
[50] Zavala J A, Casteel C L, DeLucia E H and Berenbaum M R, 2008, Anthropogenic increase in carbon dioxide compromises plant defense against invasive insects. Proceedings of the National Academy of Sciences, USA, 105:5129–33
[51] Burdon JJ, 1987, Diseases and Population Biology. New York: Cambridge Univ. Press
[52] Dalla Marta A, Magarey R D and Orlandini S, 2005, Modelling leaf wetness duration and downy mildew simulation on grapevine in Italy. Agr. Forest. Meteorol. 132: 84-95
[53] Lambers H, Chapin F S and Pons T L (2008) Plant Physiological Ecology, 2nd edn. Springer Science Business Media
[54] Agrios G N, 2005, Plant Pathology. 5th edn. Elsevier, USA, p. 922.

A Brief Author Biography

S. S. SREENIVAS, PhD, FSBA, FSAB, FSARSD, FAELS: Retired chief Technical Officer (Crop Protection) at ICAR-Central Tobacco Research Institute. Research areas of interest are Disease epidemiology, chemical control, integrated disease management and Bio-control strategies.

