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PLANT PROTECTION

Influence of Climatic Change on Pests and Diseases of Flue-Cured Virginia (FCV) Tobacco in India- Need for Potential Strategies

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ABSTRACT

Increased greenhouse gases are a severe issue world over. Climate change is likely to influence the epidemiology of diseases and pests. A change in climate in the recent past has influenced disease and pest cycle and their epiphytotic in many crops. Flue-Cured Virginia (FCV) tobacco grown in Andhra Pradesh (A.P) and Karnataka, India, in an area of about 2.2 lakh ha produces around 230 M.Kg annually. The crop is a major commercial crop with a lot of export potentiality and farm economy. FCV tobacco is grown in Karnataka as rainfed, while it is an irrigated crop in Andhra Pradesh (AP), which suffers due to many pests and diseases in nursery and field crops resulting in economic loss. Though, suitable crop protection strategies have been in practice hitherto, minor diseases and pests have evolved as a major concern due to changes in climate over a period. Crop protection strategies are needed to cope-up with the changed climatic conditions like temperature rise and periodical droughts.

HIGHLIGHTS

- Agriculture in India is highly vulnerable to projected temperature increases and changed rainfall pattern.
- Climate change has a significant influence on plant growth and crop-biotic interaction.
- FCV tobacco a major commercial crop needs the right management strategies to cope up with the weather vagaries.
- Efforts are needed to popularize eco-friendly, bio-control management schedules to sustain the quality and quantity of tobacco.

Keywords: Climate change, FCV tobacco, pests and diseases, crop protection

Climate change due to greenhouse gases is likely to bring changes in the ecosystem influencing crop growth, plant pathogens, and microbial environment. The increase in atmospheric temperatures due to increased levels of greenhouse gases, viz., CO_2, CH_4, O_3, N_2O, and CFCs, is a severe concern. Researchers have conclusive information about the increase in global average temperatures and change in rainfall patterns in recent times (Balling *et al.* 1987; IPCC 2001; Fauchereau *et al.* 2003). Global temperatures are expected to reach 1.1 - 5.4°C by the end of the next century, and CO_2 concentration in the atmosphere raised from 280 ppm to 370 ppm, which is likely to be doubled by the end of 21st century (Etheridge 1996; Keeling *et al.* 1995; IPCC 2007). India is highly vulnerable to climate change conditions as it is projected to a temperature rise of 2° to 6 °C during the 21st century in South Asian zones (Ravindranath 2007). Increased temperatures may favor some plant pathogens in a positive

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manner leading to disease epiphytotic (Evans *et al.* 2007; Richerzhagen *et al.* 2011). Precise information on various physical aspects like soil-structure, quality, and water-holding capacity is necessary to understand changes in microbial dynamics under predicted climatic conditions. Temperature, water, and CO_2 are the three main weather entities responsible for pathogen development and disease appearance. Reviews have appeared on various issues of climate change on plant pathogens and their interaction in general. Climate change impacts pathogen development and changes host susceptibility (Harwell *et al.* 2002). Climate change may bring changes in disease scenarios likely by evolutionary potential and increased adoption process by the advantage of shorter life-cycles of pathogens (Davis *et al.* 2005; Legler *et al.* 2012). Disease triangle involving susceptible host, virulent pathogen and congenial weather is an ideal phenomenon in disease epiphytotics (Schumann and D'Arcy, 2006; Scholthof 2007; Grulke 2011). Temperature and moisture together play a crucial role in making host plants vulnerable to diseases due to reduced resistance gene expression and the insurgence of virulent nematode populations (Boyer 1995; Mc Elrone *et al.* 2001; Garrett *et al.* 2006; Caffarra *et al.* 2012). Changes in gene expression due to physiological alterations in host plants result in different host-pathogen interaction (Colhoun 1973). Climate change also favors pests in general due to changed host physiology and metabolites. Elevated CO_2 levels may induce lengthened larval developmental periods and shifting hosts due to a changed nutritious state (Hunter 2001). Flue-Cured Virginia (FCV) tobacco is a major commercial crop in India is vulnerable to weather changes resulting in losses both in quantity and quality. Research attempts are towards developing climate resilient practices to cope-up with the changed climatic scenario (Ramakrishnan *et al*. 2019). The article is a review on possible influence of climate change on plant pathogens and pests, and focuses on challenges and opportunities in crop protection strategies.

Flue-Cured Virginia (FCV) tobacco cultivation in India

Flue-Cured Virginia (FCV) tobacco grown in Andhra Pradesh and Karnataka the two southern states of India, is an important commercial crop. The produce has a lot of export potential, and around 230 m.kg is being exported annually. Tobacco is a livelihood for about 3.6 crores of people, with 0.6 crores of farmers and 3 crores of farm and industrial laborers. Tobacco cultivation, in the backdrop of environmental concerns, needs better management of natural resources like land, water, and genetic resources to make it more resilient in the changing climatic situation. Cyclic droughts (late onset, midseason, and terminal) are forewarning for better crop production technologies with resistant and drought-tolerant varieties (Bhadwal *et al.* 2007). Both the quantum and rainfall distribution have a bearing on the sustainability of the crop quantity and quality. Each crop zone *viz*., Northern light soil (NLS), Southern light soil (SLS), Southern black soil (SBS) and Karnataka light soil (KLS) has a different climatic condition predisposing and favouring a set of diseases and pests. Crop needs timely crop protection measures to major pests and diseases to maintain quality/quantity for retaining the international market.

Impact of climatic change on pests and diseases

Weather plays a major role in disease initiation and the spread of major diseases in FCV tobacco. Any change in climatic situation has a great influence on crop pathogen interaction and hence, calls for a precise strategy. Rise or a slight fluctuation in temperature is likely to alter crop-season climate patterns which influences pathogen development. Excess rainfall, leaf wetness and humid warm weather pre-dispose nurseries to diseases. Damping off by *Pythium aphanidermatum* (Edson) Fitz.; *P. myriotylum* (Dreschler), collar rot- *Sclerotium rolfsii,* and Soreshin -*Rhizoctonia solani* Kuhn are devastating diseases of economic importance in early nursery phase. *Phytophthora parasitica* var. *nicotianae* (Breda de Haan) Tucker occurs as leaf blight during mid-nursery period on the foliage due to rain splash of zoospores of the pathogen from soil, while black shank infection occurs due to soil-borne propagules such as chlamydospore and oospores. Humid, warm weather after rains and optimum soil temperature favor black shank disease. Heavy rains after prolonged drought influence the disease spread. High humidity favours the sporulation of majority of fungal and oomycetes pathogens. Optimal temperatures range of 25-30°C was reported for *Phytophthora* and *Fusarium* (Norse, 1973; Shenoi *et al.* 2003; Paul and Munkvold, 2005; Manstretta and Rossi, 2015); leading to heavy disease pressure. Leaf wetness for a prolonged period is critical for disease development by foliar pathogens like *Cercospora*, *Colletotrichum* and *Alternaria* in tobacco (Magarey *et al.* 2005; Granke and Hausbeck 2010; Clarkson *et al.* 2014). Rainfall has a differential role in the growth and development of some fungal pathogens. *Erysiphe cichoracearum* and *Phytophthora parasitica* two important pathogens of economic importance have been checked due to changed rainfall patterns and the introduction of resistant/ tolerant varieties is an example. Water stress on some pathosystems shows a negative effect with lower infection rates under conditions of low RH by several foliar pathogens (Huber and Gillespie 1992; Dalla Pria *et al.* 2006). Wilt by *Fusarium oxysporum* f.sp.*nicotiana* increases as the crop gets exposed to drought (Schoeneweiss 1975). Plants exhibit fewer symptoms when subjected to drought stress due to poor root development (Huisman 1982; Pennypacker *et al.* 1991). High temperatures lead to water stress which may alter resistance mechanisms in resistant/tolerant varieties due to altered physiology and make crops susceptible to disease (Newton and Young 1996). Elevated CO_2 levels may be congenial for the rapid sporulation of pathogenic fungi and may increase the severity of disease due to increased virulence by *Fusarium oxysporum*. (Hibberd *et al.* 1996; Coakley *et al.* 1999; Chakraborty *et al.* 2000; Váry *et al.* 2015). Shenoi *et al.* (1995; 2003) reported the cumulative effect of certain weather factors on disease initiation and spread in epiphytotic proportions. High daytime temperatures (>31°C) and low night temperatures (<20^0 C), more than 80%-night RH with more rainy days play a role in the disease epiphytotic in the nursery by *Colletotrichum tabacum* (Boening). Concentration of CO_2 may play a positive role in increased infection by Colletotrichum and fecundity (Chakraborty *et al.* 2000; Chakraborty and Datta 2003. Brown spot by *Alternaria alternata* (Fries) Keissler is more severe during the wet weather in night hours coinciding with the harvesting season of the late planted crop. More sunshine per day (> six hours) and less than 60% RH during day hours are critical factors for the disease epiphytotics. Any deviation in the weather conditions may reduce the disease pressure or change infective stage due to adaptability by the pathogen. According to Leach (1967), diaurnal sporulators like *Alternaria* sp. respond to fluctuations in temperature and light. It is reported in FCV tobacco that more number of wet nights favor conidial production and germination, while more sunshine hours for conidial liberation and dispersal of *A. alternata*. These two factors are required to complete the disease cycle (Rotem 1994). Infected stubbles act as a source of primary inoculums for *Alternaria alternata*, with several weed hosts acting as collateral hosts (Karunakara Murthy 2001). Elevated CO_2 may bring down the decomposition rate increasing pathogen survival on residues leading to the early appearance of the disease. Increased CO_2 rates may result in severe *Cercospora* leaf spot disease leading to poor quality of leaf (Mc Elrond *et al*. 2010).

Root-knot nematode *Meloidogyne* spp. is a serious pest in tobacco, causing enormous damage both in nursery and field crop (Hussaini 1983). Ramakrishnan *et al.* (2001) studied the absolute density and frequency of root-knot nematodes in the track. Temperature changes might bring positive or negative changes in nematode density (Ruess 1999). Losses will be of many folds when root-knot nematodes interact with other fungal pathogens. The nematodes are damage not only through direct infestation but also, by subsequent entry of secondary pathogens, such as fungi and bacteria (Powell 1971). Root-knot nematodes predispose crops to wilt caused by *Fusarium oxysporum* forming complex resulting in significant yield and quality losses (Ramakrishnan *et al.* 2008). Root-knot nematodes play a role in 'K' deficiency and interact positively with *Alternaria alternata* in aggravating the K deficiency symptoms in FCV tobacco crop. Temperature has a crucial role on nematode development and population levels (Dong *et al.* 2013). Soil nematodes are influenced not only by direct warming also, due to the changed soil micro-environment. Nematode survival through overwintering and over-summering is affected by temperature and relative humidity. Soil-temperatures above and below the ambient temperature range may cause less population build-up (Sivapalan 1972; Sivapalan and Gnanapragasam 1975). Warming in the daytime had a stronger negative effect on soil nematodes than warming in the nighttime due to changes in soil-moisture levels (Xiumin *et al.* 2017). Water stress directly influences nematodes and indirectly due to changes in plant communities. *Xiphinema* nematodes a vector for ring spot virus in tobacco (Douthit and Mc Guire 1978) are likely to alter the stage of infection due to drought. Poor soil moisture might also inhibit the activity of vector nematode in preventing the spread of the virus they transmit. High humidity levels and flooding are more congenial for pathogen virulence and are expected to favour epidemics by contact-transmitted viruses like TMV (Johnson 1929). Humidity increases the chances of wild fire by *Pseudomonas tabaci* as it plays a role in the establishment of aqueous apoplasts, a virulence-promoting mechanism in pathogens (Xin *et al.* 2016; Schwartz *et al.* 2017). Elevated CO_2 is also, likely to increase bacterial diseases (Shin and Yun 2010). In a tripartite biotic interaction, the vector population may be affected at elevated CO_2 levels while may not be detrimental to virus (Trębicki *et al.* 2016).

Aphid spp. *Myzus nicotianae* and *M.pericae*, caterpillar *Spodoptera litura*, budworm *Helicoverpa armigera* and stem borer, *Scrobipalpa heliopa* are the common pests in FCV tobacco (Sridhar 2016; Venkateswarlu *et al.* 2018). Cloudy and humid weather with low temperatures followed by a warm climate leads to an out-break of aphid infestation. Warm climate is predicted to favor the early appearance of aphids on crop plants and is an indicator of the climate warming process (Fleming and Tatchell 1995). This may increase the chances of vector-borne virus infections. Aphids not only cause severe damage to tobacco leaves but also as vectors for some viruses like Cucmber mosaic, Potato virus Y, Tobacco etch virus, and Rosette. Severe aphid infestation leads to the development of sooty mold by *Fumago vegans* on the honeydew secretion resulting from excessive feeding by aphids. Effects of Moisture and CO_2 on insect pests can be potential factors for increasing damage in global climate change (Hamilton *et al.* 2005). Elevated CO_2 influences photosynthetic activity and production of secondary metabolites, especially simple sugars, which may bring epidemics by vector-borne viruses indirectly due to altered vector behavior (Zavala *et al.* 2008; Venkatraman 2016). Aphids and Whitefly as vectors transmit viral diseases in tobacco and respond to climatic changes because of their short generation times. Though an optimal temperature of 25–28 °C is ideal for whitefly virus vector species *Bemisia tabaci* (Wagner 1995), more generations were observed at 31-33 °C (Muniz and Nombela 2001). This kind of response of *Bemisia tabaci* to temperature change increases the risk of epidemics of leaf curl virus, *Ruga tabaci*. Aphids respond even to small changes in mean temperatures because of their low developmental threshold temperatures, short generation times and more life cycles per season (Harrington *et al.* 2007). With a temperature increase by 2°C, aphids are likely to experience more life cycles per season (Yamamura and Kiritani 1998), thereby increasing damage and spread of vector-borne virus diseases. Thrips, *Frankliniella fusca* also, respond similarly and cause damage by spreading Tomato Spotted Wilt Virus (TSWV) disease. Increased temperature and more days with precipitation have a positive effect on thrips activity (Lowry *et al.* 1992; Morsello *et al.* 2008). Polyphagus pest tobacco caterpillar, *Sodoptera litura* responds positively to a wide range of environmental conditions (Chellaih 1985) to cause damage by voracious feeding. Severe drought can cause damage to the crop by Caterpillar infestation. Tobacco ground beetles, *Mesomorphus villiger,* and *Spodoptera exigua* are minor and sporadic in nature and cause substantial damage to the yield and quality of tobacco under friendly conditions. These pests are active in cooler climates and nocturnal in habit. Soil pests may be less affected by temperature changes due soil providing an insulating medium buffering temperature change (Bale *et al.* 2002). Prolonged drought favours stem borer *Scrobipalpa heliopa* damage in severe manner and predispose crop to wilt.

Crop Protection strategies in the changed scenario

Impact of climate change on insects and pathogens is complex, with some changes favoring pathogens and insects. Precise information on pathogen-environment interaction is necessary under changed climatic conditions to manage damage to the crop. Plant protection measures in tobacco revolve around safe and minimal application of pesticides as the product is export-oriented with stringent global regulations on pesticide residue levels. There is a strong need to evolve plant protection strategies to suit changing climatic situation. Changed weather may revitalize dormant pathogens and may lead to a shift in the time of disease on the crop. Though physiological changes may enhance resistance in crops, in some pathosystems, breakdown may happen due to temperature-sensitive resistance gene mechanism. Fungal pathogens respond to asymmetric fluctuations of weather conditions like temperature necessitate strategies (Scherm and Van Bruggen 1994). Temperature and moisture stress together play a vital role in increasing the vulnerability of crops to diseases due to reduced resistance gene expression and of new race development in pathogens (Fraser and Laughlin 1982; Canto and Palukaitis 2002). Breeding programmes for new cultivars to perform better should be towards the incorporation of resistance genes that can withstand temperature fluctuations and drought tolerance. Water regime change may influence increased rates of native bio-control agents detrimental to the pest population. Serious efforts are to be made to utilize native strains against pathogens. Increased rain-fall pattern is likely to change the crop diversity and shift to new varieties resulting in a new disease cycle. Higher temperatures proved critical to aphids and vulnerable to natural predators (Awmack *et al.* 1997).

Strategies for the use of natural predators which can withstand climate changes are to be made to check pathogens. Bio-control agents *Bacillus subtilis* and *Trichoderma* spp. are less affected (Ghini *et al.* 2011) and can be infused in the crop protection programme. Tray medium can be fortified with bioagents like *Trichoderma asperelloides*, *Paecilomycis lilacinus* etc., as an efficient delivery mechanism to build inoculum levels of bio-agents in main field. Prolonged periods of leaf wetness are essential for the survival of bio-control agents and development, hence a need for a strategy to deliver bioagents. Higher temperatures act negatively in case of bio-agents when used as foliar sprays. Use of NPV, *Bacillus thurigiencis* var. Kurstaki and *Verticillium lecanii* may fail due to temperature sensitivity. Efforts are needed to improve delivery system with more efficient strains which can withstand temperature fluctuations to perform better. Climate change may alter the morphology and texture of leaf which may change pesticide retention. Rainfall events predicted by climate change may necessitate more sprays of contact fungicides on crop, adding to the cost of cultivation. Hence, a new pesticide delivery mechanism with a more precise delivery system has to be developed. Non-chemical approaches like soil-solarization and neem cake amendment in conventional seed bed management can be a better option to make use of increased temperature. Temperature rise may demand more irrigation and hence, there is a need to improve water-use efficiency to improve for plant vigor. No studies are conclusive on how climate change may affect chemical control measures. Good Agricultural Practices with sanitation measures help to reduce virus diseases. Elevated CO_2 fertilizing effect encourages inoculums levels due to poor degradation, increasing saprophytic growth of pathogens on the previous crop residue needs suitable agronomic practice. Persistence of plant protection chemicals and translocation in plant system may wary with change in climatic factors.

The possible development of new strains may result in development of fungicide resistance. Earlier onset of warm temperature could result in an early appearance of fungal diseases in nursery leading to severe epidemics and increases the number of fungicide applications leading to development of resistance. Repeated application of insecticides required in the wake of multiple generations of pests in a season will increase the probability of insects developing resistance (Georghiou and Taylor 1986). Hence, identification of new molecules, time and mode of delivery to contain the disease out-breaks has be taken up. Climate change vs crop has to be precisely studied through dynamic simulation models in different climatic zones (Kickert *et al.* 1999). Increased temperatures are likely to affect plant phenology by earlier germination of seeds, plant flowering etc leading to early appearance of diseases and pests (Charkraborty and Datta 2003) which needs to be addressed by developing dynamic simulation models. Integrated pest and disease management strategies need to be insulated with drought and disease/pest tolerant varieties, tray nursery seedlings, boosting the crop with starter fertilization, and foliar application of 'N' & 'K' to sustain the crop in fluctuating weather situations. Development of an early warning system for pests and diseases in relation to extreme weather events needs to be perfected, incorporating local weather changes. Assessment of risk and vulnerability of crops to different climate change scenarios at different climatic zones is to be done through probability distribution maps (PDM) to identify potential pathogen areas of endemism (Morales and Jones 2004) to time the plant protection measures. Epidemiological studies for forecasting and prediction models have to be developed for all climatic zones. Geographic information system (GIS) based mapping of major pests will be of much value in the changed weather scenario in different cropping zones.

CONCLUSION

Climate change is a worldwide phenomenon and a fore-warning for developing strategies to cope-up with the changed situations. Agricultural productivity is totally dependent on weather situations with greater emphasis on crop-pest interactions and disease dynamics. Weather factors like temperature, moisture, CO_2 concentration in the atmosphere are very crucial in the development, fecundity, and disease development of many pests and diseases. Climate change may bring positive or negative or neutral impact on pathogens and pests. Similarly, crops/varieties grown under climate conditions optimum may become susceptible to pests and diseases due to changing weather patterns. Flue-Cured Virginia (FCV) tobacco being a major commercial crop sensitive to weather, is likely to witness a sudden fall in yield and quality, which is a major criterion in exports. Therefore, it is necessary to develop strategies to cope-up with the changed climatic situations to retain the demand in the international market. Detailed studies are needed to understand the crop-pest interaction in dynamic modeling in all the micro-climatic zones where the crop is being cultivated. There is a need for augmenting and popularizing eco-friendly strategies like non-chemical approaches, use of bio-agents etc., to minimize pesticide usage and make the crop more economical for the farming community.

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