Journal of Oilseed Brassica, 2 (2): 48-55, Jul 2011

Impact of Climate Change on Pests and Diseases of Oilseeds Brassica - the Scenario Unfolding in India

C. Chattopadhyay[1], B.K. Bhattacharya[2], Vinod Kumar[3], Amrender Kumar[4] and P.D. Meena[3]

[1]Division of Crop Protection, Indian Institute of Pulses Research (ICAR), Kanpur 208024;
[2]Crop Inventory and Modelling Division, Agriculture-Forestry and Environment Group, Space Applications Centre (ISRO), Ahmedabad 380015;
[3]Directorate of Rapeseed-Mustard Research (ICAR), Sewar, Bharatpur 321303;
[4]Division of Forecasting & Econometric Techniques, Indian Agricultural Statistics Research Institute (ICAR), New Delhi 110012
Coreesponding author: chirantan_cha@hotmail.com

Abstract

Effect of climate change on agriculture or more precisely on insect pests and diseases of agricultural crops is multidimensional. Magnitude of this impact could vary with the type of species and their growth patterns. The elevated production could be off-set partly or entirely by the insect pest or pathogens. It is, therefore, important to consider all the biotic components under the changing pattern of climate. World over research on effect of climate change on pests and diseases of crops is inadequate. Several diseases and insect-pests have been noted to be showing higher level of infestation on Oilseeds Brassicas in India, which have been discussed. The article also looks at different strategies to cope with effects of climate change on insect-pests and diseases of rapeseed-mustard crops with a proposal for *Integrated Decision Support System (IDSS)* for Crop Protection Services that suggests the operational focus, research priorities and aspects of capacity building.

***Key words**: Climate change, impact, pests, India, Brassica*

Introduction

Climate change has become a household topic of discussion with more scientists getting involved in scientific research on the aspect while politicians trying to derive mileage from the paradigm. The last decade of the 20th century and the beginning of the 21st have been the warmest period in the entire global instrumental temperature record. Climate change is defined as any long-term significant change in the "average weather" that a given region experiences or in other words it is the shift in the average statistics of weather for long-term at a specific time for a specific region. Average weather may include temperature, precipitation and wind patterns. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. These changes can be caused by dynamic process on earth, external forces including variations in sunlight intensity and by human activities. Climate change in the usage of the Intergovernmental Panel on Climate Change (IPCC) refers to 'a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically for decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC, 2007).

Increased emission of carbon dioxide (CO_2) and other green house gases, predominantly methane (CH_4) and nitrous oxide (N_2O) have been ascribed as the main agents causing increase in global temperature. The second assessment report (AR2) of IPCC indicated that the increase of greenhouse gas concentrations leads to an additional warming of the atmosphere and the earth's surface. Concentration of CO_2 has increased from about 280 to almost 360 ppmv since preindustrial time, CH_4 from 700 to 1720 ppbv and N_2O from about 275 to about 310 ppbv. This development is ascribed to the magnitude of human intervention mostly in terms of fossil-fuel use, change in land-use pattern and agriculture. Global mean surface temperature has increased by 0.3-0.6°C since the late 19th century, a change that is unlikely to be entirely natural in origin. The temperature increase is widespread over the globe and is greater at higher northern latitudes (*http://www.ipcc.ch*). According to IPCC, cold days and cold nights have become less frequent and hot days, hot nights, heat waves more common. Rising temperature also affect the pattern of precipitation. Changes in rainfall pattern have already been noticed. The IPCC reports that the frequency of heavy precipitation has increased over most land areas, which is consistent with warming and increase of atmospheric water vapour. Based on the trends since 1900, precipitation significantly increased in eastern parts of North and South America, northern Europe and northern, central Asia whereas, declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has increased since the 1970s.

Effect of climate change on agriculture or more precisely on insect pests and diseases of agricultural crops is multidimensional. Magnitude of this impact could vary with the type of species and their growth patterns. With the change in the temperature and rainfall pattern the natural vegetation over a region is facing a new phase of competition for survival. The fittest species are more likely to dominate in the changing pattern of climate. It may be assumed that the vegetation tolerating high temperature, salinity and having high CO_2-use-efficiency could fair better than other species. Any change in the managed vegetation system i.e. agriculture and forestry will directly affect the socio-economic implications of the regions involved. IPCC in its report of 1995 predicted that a double increase in the CO_2 level will increase yield by 30% in several crops. The elevated production could be off-set partly or entirely by the insect pest, pathogens or weeds. It is, therefore, important to consider all the biotic components under the changing pattern of climate. There is also thought about shorter winters, which may affect the oil yields of the rapeseed-mustard crops.

Climate change and pest scenario in India

World over research on effect of climate change on pests and diseases of crops is inadequate (Huda *et al*., 2005). In India, there is limited effort in this area for any insect-pest or disease of any crop (Subba Rao *et al*., 2007; Chattopadhyay and Huda, 2009). However, at the genomic level, advances in technologies for the high-throughput analysis of gene expression have made it possible to begin discriminating responses to different biotic, abiotic stresses and potential trade-offs in responses. At the scale of the individual plant, enough experiments have been performed to begin synthesizing the effects of climate variables on infection rates, though pathosystem-specific characteristics make such synthesis challenging. At the population level, the adaptive potential of plant and pathogen populations may prove to be one of the most important predictors of magnitude of effects of climate change. Ecologists are now addressing the role of plant disease in ecosystem processes and the challenge of scaling-up from individual infection probabilities to epidemics and broader impacts (Garrett *et al.*, 2006). Swaminathan (1986) indicated that the number of diseases on the same crops were much higher in tropics than under temperate conditions to indicate how rising temperatures could impact occurrence of plant diseases on agricultural crops. Presently, most of the work related to climate change vis-à-vis plant diseases is going on in rice (blast, bacterial leaf blight), wheat (*Puccinia*, *Septoria*) and horticultural (*Meloidogyne*) crops. The trend indicates that severity of majority of diseases is found to be higher with elevated CO_2 levels (Chakraborty, 2008), an off-shoot of climate change. It is also being opined that climate change could lead to a changed profile (variants) of pathogen, insect-pest ("climate change can activate 'sleeper' pathogens, whilst others may cease to be of economic importance" – Bergot *et al*., 2004). The facultative pathogens with broad host range may survive better. There is also possibility of broadening of host range of the facultative pathogens. The need for further work in this area has been highlighted in adaptation experiments using twice-ambient CO_2, which increased the aggressiveness (Chakraborty and Datta, 2003) and fecundity (Chakraborty *et al*., 2000) of *Colletotrichum gloeosporioides*, which causes anthracnose of tropical legumes.

Elevated CO_2 may modify pathogen aggressiveness and/or host susceptibility and affect the initial establishment of the pathogen, especially fungi, on the host (Coakley *et al*., 1999; Plessl *et al*., 2005; Matros *et al*., 2006). In most examples, host resistance has increased, possibly due to changes in host morphology, physiology and composition. Increased fecundity and growth of some fungal pathogens under elevated CO_2 has also been reported (Hibberd *et al*., 1996; Coakley *et al*., 1999; Chakraborty *et al*., 2000). However, it has been reported that greater plant canopy size, especially in combination with humidity and increased host abundance, can increase pathogen load (Manning and Tiedemann, 1995; Chakraborty and Datta, 2003; Mitchell *et al*., 2003; Pangga *et al*., 2004). Sporulation by the pathogenic fungi could be 15 - 20 folds higher, leading to massive increase in the pathogen (Mitchell *et al*., 2003). New strains may develop, with adaptation occurring faster and their evolution may get accelerated (Coakley *et al*., 1999). Among the 27 diseases examined under elevated CO_2 levels, 13 caused higher crop losses than expected. Ten of the diseases had a reduced impact, and four had the same effect as they do now (NSW DPI, 2007).

Low solar radiation and short-day periodicity could result in higher infections by *Fusarium, Sclerotinia* and *Verticillium* (Nagarajan and Muralidharan, 1995). Root rot is an emerging threat for rapeseed-mustard production system, recently reported from the farmers' field in some pockets of the country (Meena *et al*., 2010), which was initially identified as stand-alone bacterial or fungal incidence or in combinations (*Erwinia carotovora* pv. *carotovora, Fusarium, Rhizoctonia solani* and *Sclerotium rolfsii*). Keeping in view the fact that some isolates of *Alternaria brassicae* sporulated at 35^{o}C and several isolates had increased fecundity under higher RH, it seems that as per recent changes towards warmer and humid winters, being in line with current projections for future climate change (Waugh *et al*. 2003), existence of such isolates could pose more danger to the oilseed Brassicas due to Alternaria blight in times to come. The immense variation available among only thirteen representative isolates of *A. brassicae* also indicates their ability to adapt to varied climatic situations (Goyal *et al*., 2011). Powdery mildew (*Erysiphe cruciferarum*) in oilseed Brassicas was mostly occuring in Gujarat state barring stray incidences elsewhere, the appearance of the disease use to occur from late January. However, in recent times the disease has been found to be occuring in other oilseed *Brassica* growing states *viz*., Haryana, Central UP, MP, parts of Rajasthan and Bihar with the disease making its appearance even in December possibly due to shortening of cold spell during the crop period. Bihar hairy caterpillar (*Spilarctia obliqua*) surprisingly on mustard has been noted to be on the rise. Oilseeds Brassicas have been affected a lot by the Painted bug (*Bagrada cruciferarum*) in the western and by saw fly (*Athalia proxima*) in the eastern India.

Presently, the India Meteorological Department (IMD, GoI) and the National Centre for Medium Range Weather Forecasting (NCMRWF) in coordination with scientists from other agencies as ICAR, etc. are regularly issuing location-specific weather forecast and agro-meteorological advisory as per different climatic conditions and cropping systems. Indian Council of Agricultural Research (ICAR) recently launched National Initiative on Climate Resilient Agriculture (NICRA) in February, 2011 to boost research on the impact of climate change and its mitigation at national level. The project aims to enhance resilience of Indian agriculture to climate change, climate vulnerability through strategic research and technology demonstration. Research on adaptation and mitigation covers crops, livestock, fisheries and natural resource management. It also demonstrates site-specific technology packages on farmers' fields for adapting to current climate risks. This will certainly enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and its application (*http://www.icar.org.in*). The mitigation of the adverse effect of climate is challenging. Acquaintances between pragmatic and modelling studies could prop-up swift advancement in perception, prediction of climate change effects.

The way ahead:

There are several insect-pest and disease forecasting networks across the globe viz., maize (EPICORN – for Southern corn leaf blight), tomatoes and potatoes (EPIDEM, TOMCAST, BLITECAST – for early and late blights), apple (Maryblight, EPIVEN – for fire blight and scab), etc. Further research advancement led to development of weather-based location-specific forewarning models based on multiple or stepwise regression, discriminant function analysis, artificial neural network for diseases and insect-pests (Desai *et al*., 2004; Chattopadhyay *et al*., 2005a,b; 2011; Laxmi and Kumar, 2011). These have been validated with success, even with issue of agro-advisories for public use.

At present, remote sensing (ISRO) data are also being used in generating weather forecasts, providing crop estimate in terms of net sown area and yield, issued in operational mode for the last few years with reasonable accuracy for oilseed Brassicas as well apart from rice, wheat and potato, thanks to ICAR-ISRO (SAC) collaboration under MoA (DAC)-funded project FASAL (Forecasting Agricultural output using Space, Agrometeorological and Land-based observations). Crop production has been forecasted at national level under FASAL using multi-date temporal AWiFS (Advanced Wide Field Sensor on IRS-P6; 56 m x 56 m) and RADAR (RAdio Detection and Ranging) data. Two forecasts are made during the season at different crop growth stages. Encouraged by these successes, the IMD envisages implementation of FASAL initially at 46 centres, which is likely to be extended to 130 stations in due course (IMD, 2011)

Figure 1: Proposed architecture of IDSS for Crop Protection Services

Research efforts have been put to apply or refine ground-based models using satellite-based spatial weather and high-resolution remote sensing (RS) observations for mustard aphid infestation (Bhattacharya *et al*., 2007a; Dutta *et al*., 2008). Use of remote sensing (RS) and Geographic Information System (GIS) could be explored for analysis of satellite-based agro-met data products, mapping geographical distribution of pests, delineating the hotspot zones. Super-imposition with causative abiotic and biotic factors on visual pest maps can be useful for disease forecasting. Since, diseased plants increase reflectance particularly in chlorophyll absorption band (0.5-0.7 mm) and water absorption bands (1.45-1.95mm), forecasting plant disease is possible by remote sensing. Though information on this aspect is scanty, disease severity and yield loss estimation using changed reflectance pattern of diseased plants can be attempted. Routine monitoring at surface for weather and by remote sensing could help predict epidemic well before first appearance of the disease on the crop, giving a positive edge to make accurate decision related to disease management. Similarly, preparation of mustard crop mask, mapping of spatial distribution of aphid (population density) growing zones and prediction of its growth, dates of severe pest infestation (peak population) at each grid level was possible (Bhattacharya *et al*., 2007a; Dutta *et al*., 2008). It has also been possible to detect Sclerotinia rot-affected mustard using remote-sensing technology (Dutta *et al*., 2006; Bhattacharya *et al*., 2007b). These successful experiences could certainly be effective boosters for any future endeavour. But the potential benefits of short-to-medium range weather forecast from numerical weather prediction (NWP) models or future climate projections have been least harnessed in India for regional crop protection services. Recent momentum to assimilate more updated satellite-based spatio-temporal atmospheric and land surface products (Bhattacharya, 2011) from Indian geostationary satellites (Kalpana-1, INSAT 3A) for high resolution (5-15 km) weather forecasts from advanced NWP model such as WRF (Weather Research and Forecasters) is encouraging. Such regular high-resolution forecast products are available for the registered users (http://www.mosdac.gov.in).

Very soon a National Crop Forecasting Centre (NCFC) is scheduled at IARI, New Delhi under the behest of MoA (DAC). Therefore, an *Integrated Decision Support System (IDSS) for Crop Protection Services* (Figure 1) can be imagined with its evolution in a phased manner, which could have the following three components: (A) Operational focus (with periodic production of alarm zones encompassing 127 agro-climatic zones through well-tested models, forecast weather, high-resolution remote sensing data and operational crop map in the GIS framework), (B) Research priorities [(i) Development of forecast models for major insect-pests and diseases with large-scale applicability, validation in farmers' fields and model refinements, (ii) Evaluation and improvement in quality of well-validated satellite-based products, improved data assimilation approaches, (iii) field-to-satellite-based remote sensing with high-resolution observations to differentiate among crops, among phenological stages within crop growth period, biotic stresses from abiotic stresses (moisture and nutrients), normal health and (iv) development of models for minor pests and diseases in view of climate change scenario], (C) Human Resources renewal [(i) creation of experts on handling of spatial data, who could be brave enough to think differently, bold enough to believe that as a team they could bring a positive change in the present practices of pest management and talented enough to do it, (ii) familiarization of policy makers with more of digital products for interpretation and (iii) regular feedback mechanism from farmers through Village Resources Centre (VRC) network using satellite communication].

On-line decision support systems to forecast different diseases are in use across the globe viz., canola light leaf spot (*Pyrenopeziza brassicae* on http://www.rothamsted.bbsrc.ac.uk/Research/CentresContent.php?Section=Leafspot&Page=llsforecast) and Phoma stem canker (*Leptosphaeria maculans*, *L. biglobosa* on http:/www.rothamsted.bbsrc.ac.uk Research/Centres Content.php?Section=Leafspot &Page=phomaforecast). Models of plant disease have now been developed to incorporate more sophisticated climate predictions. With support from ICAR, we too have designed and implemented web-based forecast software (www.drmr.res.in/aphidforecast/index.php) for prediction of mustard aphid (*Lipaphis erysimi*) on oilseed *Brassicas* for different locations in India. This software uses weather parameters as independent variables to predict crop age at time of first appearance of aphid on crop, peak number of aphid and crop age at peak population as dependent variables, well ahead of actual occurrence of the event.

In view of changing climate, the devised and to-be-born models need to be oriented to dynamic mode. The models already developed are based on some observations on meteorological parameters, insect-pests, diseases recorded in the past and hence are based on previous pest-weather correlation. However, with change in climate, the pest-weather relationship is also bound to change apart from behaviour of the hosts, newer varieties, cropping practices, etc. (Chakraborty *et al*., 2008). Dynamic models incorporate the recorded data of each crop season for a particular pest to suitably revise itself and thus remain stable, relevant enough to continue providing accurate forecast.

But due to inadequacies in hard-core data, the vital questions still haunt – whether there has really been changes in climate in the agro-ecological regions growing major crops in India? What are the possible impacts of climate change on diseases and insect-pests of major crops or any shift in pathogen / insect-pest status with change of climate in the agro-ecological region growing major crops in India? We may have seen some changes in scenario of insect-pests, pathogens and ascribed them to changed climatic patterns. However, establishing such correlation through research remains to be done in India.

The technique in System of Rice Intensification is reported to have helped 55-70% reduction in major diseases and insect-pests of the crop in Vietnam during 2005-06 (Uphoff, 2007), which seems an effective strategy to cope with the effects of climate change. Similar efforts would be warranted to adapt to and manage the effects of climate change on pests and diseases of different crops. Accordingly, there could be a pro-active approach to breed for resistance to pests, pathogens and their variants likely to be dangerous apart from modelling the future possible pest and disease scenario in major crops. Monitoring of variability in major insect-pests, pathogens and nematodes affecting agricultural crops to keep track of upheaval of ‘sleeper races’ becoming severe under changed climate, modelling future enemies of plants and designing crops with resistance to such would-be menaces as also modifying IPM strategies suitably may need emphasis.

Today’s challenge is to ‘produce more from less’. In the era of climate change, diagnostics of pests and diseases and capacity building of farmers, extension and even research personnel for adaptation to changed pest scenario under future climates assumes significance, wherein Integrated Crop management in Private Public Partnership mode could be very effective. Farmers’ decisions are of vital importance for good yields of crops. Forecasted weather products and area-wide weather networks are becoming more prevalent. Now, the challenge is to bring continuous improvement in productivity, profitability, stability and sustainability of major farming systems, wherein scientific management of plant pests holds a pivotal role (Swaminathan, 1995). Crop loss models, representing a dynamic interaction between pests and host, are essential for forecasting losses thereof. Accurate information concerning possible yield losses due to occurrence of a pest is needed by growers or plant protection specialists to decide on cost-effective control measures. With an increasing concern for cleaner environment and discouragement for pesticide use, there is need to approach pest management through knowledge on their dynamics as an art of living with them (Zadoks, 1985). Thus, future research and education in Crop Protection in India does need to address the issue of future climates in pest management, for which fund requirement would certainly be lesser than many ambitious ones.

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