

CLIMATE CHANGE AND IMPACTS ON CROP PESTS—A CRITIQUE

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ABSTRACT:

Climatic variability, together with increase in atmospheric temperature and carbon dioxide do have lot of implication in agriculture sector. Latest assessment report from the Intergovernmental Panel on Climate Change (IPCC) predicts an increment in mean atmospheric temperature from 1.1 to 6.4°C toward the year 2100 with equally increasing atmospheric carbon dioxide (CO₂). Such climatic changes could profoundly affect insects both directly i.e. seasonal shifts of insects and indirectly i.e. changing plant productivity and quality, changing predators increasing insect pests population. A detailed investigation was done by analyzing various studies carried out around the globe on impact of increasing atmospheric temperature and carbon dioxide on crop pests population and crop-pest interaction. Studies reported both harmful and beneficial impacts, however benefits are least reported. A substantial expansion in high latitude and elevation of various crop insect pest distributions and is critical in temperate part of the world. Increased frequent insect outbreaks had been observed where changing climate may interfere with the induction of extended diapauses. Increase in atmospheric temperature resulted in reduction in survival and increase in developmental rate, resulting in more generations (and more crop damage) per year. New studies show that insect species living in warmer areas are more likely to undergo rapid population growth because they have higher metabolic rates and reproduce more frequently, thus climate change would create favorable conditions for growth in insect populations. Other environmental parameters like relative humidity and CO₂ is potentially important, more CO₂ in the atmosphere make plants to take up more carbon and leaves become less nutritious and results in voluminous feeding. Further studies on crop-pest interaction focusing on spatio-temporal variations are needed to have a better understanding and to quantify its future impacts.

1. INTRODUCTION

Climate change has been recognized globally as the most impending and pressing critical issue affecting mankind survival in the 21st century. The last assessment report from the Intergovernmental Panel on Climate Change predicted an increment in mean temperature from 1.1 – 6.4 °C by 2100 (IPCC, 2007). The global atmospheric concentration of green house gases (GHG) viz., carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (NO₂) has increased tremendously as a result of human activities from pre-industrial era. Increasing concentration of these gases is expected to have great effect on global climate change and thereby affect on agriculture (Cannon 1998). Climate change will be an additional challenge to produce enough food grain for the ever-growing populations when crop production will have to be boosted to feed an extra three billion people living at the end of 21st century. Considering all the anticipated or expected changes, global researchers are deeply engaged in analyzing the effect of insect pest on agriculture crop. Climate change related factors such as rise of temperature, carbon dioxide atmospheric concentration rise are the major cause of concern. An attempt was done to analyze various major studies undertaken across the globe on crop insect pest and how it influences the crop. Generally, Climate change impacts on pest population include change in phenology, distribution, community composition and ecosystem dynamics that finally leads to extinction of species (Walther et al 2002). Climate change effects could either be direct, through the influence that weather may have on the insects' physiology and behavior

(Berrigan 2001). In addition, indirect effects can occur through the influence of climates on the insect's host plants, natural enemies and interspecific interactions with other insects.

2. EFFECT OF RISING TEMPERATURE

The atmosphere temperature rise is not a new phenomenon and it has started million of years ago. Scientists were analyzing the fossilized remains of leaves of trees about 55 millions years ago and they reached a conclusion that planet was undergoing a period of warming. They believe rise in global temperatures caused by a tripling of CO₂ levels during the palaeocene age and this result in soaring insect number. Climate, temperature and precipitation in particular, have a very strong influence on the development, reproduction and survival of insect pests and as a result it is highly likely that these organisms will be affected by any changes in climate. Milder and shorter winters mean that warm weather pests will start breeding sooner (Bale et al. 2002). Other changes include expanded pest ranges, disruption of synchrony between pests and natural enemies, and increased frequency of pest outbreaks and upheavals (Parmesan 2007). Many major insects are contributors to global warming because of the CO₂ they emit. Bugs and all termites are major contributor global warming. The termite will emit CO₂ from their gut because when they consume the wood and its digestion resulting emission. With every degree the global temperature rises, the life cycle of each bug will be shorter. The quicker the life cycle, the higher will be the population of pests. The general prediction is that if global temperatures increase, the species will shift their geographical ranges closer to the northern pole or to higher elevations, and increase their population size. In temperate regions, most insects have their growth period during the warmer part of the year. Due to this,

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species whose niche space is defined by climatic regime will respond more predictably to climate change while those in which the niche is limited by other a biotic or biotic factor will be less predictable. A key factor regulating the life history pattern of insect pests is temperature. Because insects are poikilothermic (cold-blooded) organisms - the temperature of their bodies is approximately the same as that of the environment. Therefore, the developmental rates of their life stages are strongly dependent on temperature. Indeed, almost all insects will be affected to some degree by changes in temperature, and there may be a multitude of intertwined effects upon insect life histories. Porter *et al* (1991) in the study mentioned the effects of temperature upon insects, including limitation of geographical range, over wintering,

population growth rates, number of generations per annum, crop-pest synchronization, dispersal and migration, and availability of host plants and refugia. The temperature increases associated with climatic changes could impact crop pest insect populations in several complex ways like (a) extension of geographical range, (b) increased over wintering; (c) changes in population growth rate; (d) increased number of generations; (e) extension of development season; (f) changes in crop pest synchrony; (g) changes in inter-specific interactions; (h) increased risks of invasions by migrant pests; (i) and introduction of alternative hosts and over wintering hosts. But all these effect of temperature on insects largely overwhelms the effects of other environmental factors (Bale et al 2002).

Common Name	Scientific Name	Temperature Range	Biology	Temperature	Biology	References
Argentine ant	<i>Lithepithema humile</i>	<18°C(64.4F)	egg laying ceases	6°C (42.8F)	activity ceases	Ebeling 1975
Cat flea	<i>Ctenocephalides felis</i>	13 ⁰ C (55.4F)	egg hatch, 6days	35°C (95F)	egg hatch, 36 hours	Silverman <i>et al.</i> 1981
House fly	<i>Musca domestica</i>	<20 ⁰ C (68F)	larval stage, 6-8 weeks	21-32°C (69.8-89.6F)	larval stage, 3-7 days	Ehmann 1997
Indian meal	<i>Plodia interpunctella</i>	20 ⁰ C (68F)	moth life cycle, 60days	25°C (77F)	life cycle, 30 days	Cox and Bell 1991
Old house borer	<i>Hylotrups bajulus</i>	20-31 ⁰ C (68-87.8F)	optimal temp. larvae	-----	--- ----	Cannon and Robinson 1985
Old house borer	<i>Hylotrups bajulus</i>	29-35°C (84.2-95F)	Optimal temperatures adults	>30°C (86F)	adult flight s	Cymorek 1968
Western drywood termite	<i>Incisitermes minor</i>	>27°C (80.6F)	peak swarming	-----	- ---- -	Harvey 1946
Western subt erranean termite	<i>Reticulitermes hesperus</i>	29-32°C (84.2-89.6F)	preferred soil temperature	-----	-----	Smith and Rust 1994
Yellow fever mosquito	<i>Aedes aegypti</i>	25-29°C (77-84.2F)	optimum larval development	26°C (78.8F)	optimal adult temperature	Fay 1964

Table 1: Effects of Temperature on Insect Biology

Temperature can impact insect physiology and development directly or indirectly through the physiology or existence of hosts. Depending on the development “strategy” of an insect species, temperature can exert different effects (Bale et al 2002). Some insects take several years to complete one life cycle – these insects (cicadas, arctic moths) will tend to moderate temperature variability over the course of their life history. Some crop pests are “stop and go” developers in relation to temperature – they develop more rapidly during periods of time with suitable temperatures. It has been estimated that with a 2° C temperature increase insects might experience one to five additional life cycles per season (Yamamura & Kiritani 1998). Warming could decrease the occurrence of severe cold events, which could in turn expand the overwintering area for insect pests. In-season effects of warming include the potential for increased levels of feeding and growth, including the possibility of additional generations. Degree-day or phenology based models are often used to predict the emergence of insects (like cabbage maggot, onion maggot, European corn borer, Colorado potato beetle etc.) and their potential to damage crops. Increased temperatures will accelerate the development of crop affecting maggots and borers – possibly resulting in more generations (and crop damage) per year.

Natural enemy and host insect populations may respond differently to changes in temperature. Parasitism could be reduced if host populations emerge and pass through vulnerable life stages before parasitoids emerge. Temperature may change gender ratios of some pest species such as thrips (Lewis 1997) potentially affecting reproduction rates. Insects that spend important parts of their life histories in the soil may be more gradually affected by temperature changes than those that are above ground simply because soil provides an insulating medium that will tend to buffer temperature changes more than the air. At higher temperatures, aphids have been shown to be less responsive to the aphid alarm pheromone they release when under attack by insect predators and parasitoids – resulting in the potential for greater predation. Increases in mean temperatures, particularly milder winters and longer summers, are highly favourable to increased aphid populations, and are thought to have caused extensions to the geographical range of wheat bulb fly, leading to increased range and severity of infestations. There is also the prospect of new pests, which may become much more important as a result of global warming. These include corn rootworms (*Diabrotica* spp.), serious pests of maize and other crops, which are spreading throughout Europe after accidental introduction from N. America,

and the Sunn insect (*Eurygaster integriceps*), which is responsible for extensive grain spoilage of wheat throughout the Middle East.

3. EFFECT OF ELEVATED CARBON DIOXIDE

One of the most studied aspects of climate change is the effect of increasing concentrations of carbon dioxide on crop and pest. In plants the carbon dioxide increases will increase the photosynthetic rates of most crop plants especially C3 plants. In addition to growing more quickly, many crop plants would become more drought-tolerant. This is because the openings in the leaves (stomata) that let carbon dioxide in also let water vapor out, and if there is more carbon dioxide, then the stomata do not need to be open as much. A rise in CO₂ generally increases the carbon to nitrogen ratio of plant tissues (Ainsworth et al.; 2002), reducing the nutritional quality for protein limited insects diluting the nitrogen content of the tissues (Coviella et al; 1999). The first reaction expected from herbivores to the increase of the C/N ratio is compensatory feeding. Insects may accelerate their food intake to compensate for reduced leaf nitrogen content. However, varied effects of carbon dioxide on insect pests have been reported some of the effects are given in table 2.

CONCLUSION

The greatest challenge facing humanity in the coming century will be the necessity to double our global food production to meet a booming increase in population by using less land area, less water, less soil nutrients, droughts from global warming. Various insect responds differently to atmospheric temperature and carbon dioxide rise and it is obvious of having varied impact depend on insect and regions. Understanding how climate change will impact on various pests especially crop pests helps agricultural scientist to orient their research on various futuristic possibilities that can help in mitigating and adapting to menace of anticipated climate change.

Increasing	Decreasing
Food consumption by caterpillars	Insect developmental rates
Reproduction of aphids	Response to alarm pheromones by aphids
Predation by lady beetle	Parasitism
Carbon-based plant defenses	Effects of transgenic <i>B. thuringiensis</i>
Effects of foliar applications of <i>B. thuringiensis</i>	Nitrogen-based plant defenses

Table 2: Effect of Increasing Atmospheric Carbon Dioxide on Various Insect Pest Biology

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