

Impact of global warming on insect behavior - A review

M.G. Sable* and D.K. Rana

Department of Entomology,
Indira Gandhi Krishi Vishwavidyalaya, Raipur-492 012, India.
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ABSTRACT

Global warming is a great concern throughout the world. Being poikilothermic in nature insects are greatly affected by changing temperature. Insect will experience additional life cycles with rapid growth rate. As a result of changes in the population dynamics including distribution and migration the reliability on current insect pest ETL will be reduced. Increased insect pests outbreak will affect agricultural production. Research on basic biology of insect, population dynamics and behavior patterns should be focused to ascertain the effect of global warming on insect behavior.

Key words: CO₂, Global warming, Insect behavior, Population dynamics.

Generally global warming refers to an increase in average global temperatures. The average global air temperature near the Earth's surface increased 0.74 ± 0.18 °C during past hundred years ending in 2005 (IPCC 2007). In atmosphere energy of incoming solar radiation is balanced by outgoing long wave radiation. Gases like water vapour (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) in atmosphere have the potential to trap the part of long wave radiation from the earth surface. These gases keep the earth warm and cause global warming or green house effect. Global warming is caused by natural as well as human activities. There are number of natural factors responsible for climate change. Some of the most prominent are volcanoes, ocean currents, forest fire etc. Among human activities, emissions of green house gases, industrialization, deforestation, fuel burning, etc are most important factor contributing towards global warming. It is not new that global warming can affect agriculture through their direct and indirect effects on the crops, soils, livestock and pests. Changed climatic conditions will also change the current crop pest scenario.

General effects on insect: Insects are considered as *poikilothermic* i.e. animals in which body temperature is variable and dependent on ambient temperature. They do not have any temperature regulating mechanism in their body. The effect of rising temperature on insect can be direct, through the influence of climatic factors on the insects' physiology and behavior or indirect, as mediated by host plants, competitors or natural enemies (Thomson *et al.*, 2010). In general increased temperature affects the pest population dynamics, development, reproduction, diapause, voltinism, winter mortality, survival rate, growth rate, migration and movement of insects. A perusal of papers published between 1985 and August 2012 reveals that most

published research papers (64%) on this topic have been published from Europe and North America, of which 29% are dedicated to Lepidoptera and 22% to Diptera (Andrew *et al.* 2013).

Increased temperature has resulted in increased northward migration of some insects, insect development rate and oviposition, potential for insect outbreaks, invasive species introductions and insect extinctions. On the other hand it has reduced effectiveness of fungi in controlling insects, reliability of current economic threshold levels, insect diversity in ecosystems and parasitism. Elevated CO₂ concentration increases food consumption by caterpillars, reproduction of aphids while it decreases insect development rates, response to alarm pheromones by aphids, parasitism and effectiveness of transgenics developed with *Bacillus thuringiensis* (Das *et al.* 2011).

Effect of global warming on insect biology: Temperature is probably the single most important abiotic factor influencing insect biology. Pests may become more active than they currently are, thus posing the threat of greater economic losses to farmers. It has been estimated that with increase of 2°C temperature insects might experience one to five additional life cycles per season (Yamamura and Kiritani 1998). The life span of Japanese beetle, *Popillia japonica* a major pest of soybean, is prolonged by 8.25% when fed on foliages developed under elevated CO₂. Also females fed on such foliages laid approximately twice as many eggs as compared to females fed on foliages grown under normal ambient conditions. Life cycle of *Aphis gossypii* Glover ranges from 20-22 days at 10-25°C, but at 30°C it will take only 6-9 days to complete the life cycle. In the cricket, *Gryllus texensis*, 6 days of elevated temperatures resulted in increased egg laying, faster egg development and greater mass gain. The increased temperature also increased activity

*Corresponding author's e-mail: sablemangesh36@gmail.com.

of phenoloxidase and lysozyme-like enzymes and enhanced resistance to the Gram-negative bacterium *Serratia marcescens*. This data suggest that heat waves could result in more numerous, disease resistant, crickets. In elevated CO₂ concentration brachypterous females of rice brown planthopper, *Nilaparvata lugens* (Stal.) laid more eggs (324.3 ± 112.3 eggs/female) on the rice plants exposed to elevated CO₂ (570 ± 25 ppm) than 380 ppm ambient CO₂ (231.7 ± 31.8 eggs). It was also reported that elevated CO₂ exhibited positive effect on BPH multiplication and resulted in more than a doubling of its population (435.4 ± 62.0 hoppers/hill) at peak incidence compared to ambient CO₂ (121.4 ± 36.8 hoppers/hill) (Prassanakumar *et al.*, 2012).

Increase in the surface temperature may have a profound effect on the initiation and termination of diapause with a subsequent change in the voltinism. Some insect species may be affected by climate change if diapause requirements have a lower chance of being met thereby disrupting developmental cycles (Ayres and Lombardero 2000). Global climate change is projected to increase temperature of the upper soil (0–5 cm) by 1.6– 3.4 °C by 2100, which is likely to have several effects on soil insects such as *Sitona spp.*, root weevils that are important in lentil in West Asia. Higher temperatures could speed up egg development, resulting in more than one generation per year of the pest (Scott *et al.*, 2010).

Effect on insect population dynamics: Global warming has great importance regarding to population size, growth, distribution and outbreak of insect pests. New research shows 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. Lower winter mortality of insects due to warmer winter temperatures could be important in increasing insect populations (Harrington *et al.*, 2001). The winter mortality of adults of *Nezara viridula* is predicted to be reduced by 15% with each rise of 1°C in Japan. Some times rising temperatures having negative affect on delicate natural enemies. For example rice brown plant hopper is 17 times more tolerant than its predator *Cyrtorrhinus lividipennis* at 40°C subsequently resulting in rise in BPH populations.

Kiritani (2006) studied a sequential change in the rice pest status due to climatic warming in Japan since 1945. The dominance of Pyralid moths from 1945 to 1965 was successively replaced by Delphacid and Cicadellid homopterans in 1965-1995 and then recently by various kinds of rice bugs. Around 65 species of multivoltine and polyphagous heteropteran bugs have been known to increase their populations among which twelve of them caused major outbreaks in Japan (Tomokuni *et al.*, 1993). Population outbreaks due to enhanced fecundity under warm condition are attributed for the widening of distribution range of the Pyralid rice pest, *Chilo suppressalis* in Hokkaido Island of

Japan (Kiritani and Morimoto, 2004). Population dynamics of three insect pest species *viz.* rice stem borer, *Chilo suppressalis*, green rice leafhopper, *Nephotettix cincticeps* and small brown planthopper, *Laodelphax striatellus* was studied over 50 years in Japan. On the basis of the light-trap data it was concluded that the population dynamics of insects show decreasing trends due to the climate change (Yamamura, *et al.* 2006).

Effect on insect pheromones: Pheromones are utilized by insects for several purposes, including alarm signalling and sexual communication. It was found that when CO₂ was elevated, aphids *Chaitophorus stevensis* did not disperse readily, but when O₃ was elevated, aphids exhibited an extreme dispersal response. The researchers think this escape behavior may explain the larger aphid populations observed under enriched O₃ conditions (Edward *et al.* 2004).

Effect of CO₂ on feeding: Increased level of CO₂ causes wide C/N ratio in plant. 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 reduced leaf nitrogen content. Caterpillars may eat larger portions of plants grown in enriched CO₂ environments due to nutrient dilution in the plant tissues. It was noted that soybeans grown in elevated CO₂ atmosphere had 57% more damage from insects (Hamilton *et al.* 2005). Honeydew excretion in rice BPH was observed to be 74.41% more under elevated CO₂ (187.6 ± 44.8 mm²/5 females) than ambient CO₂ (48 ± 20.1 mm²/5 females) (Prassanakumar *et al.* 2012).

Effect on parasitism: The life of a developing parasitoid depends on suppressing or fooling the host's immune system. Studies suggest that higher temperatures increase the probability that a host will kill its parasitoid. Parasitism of the caterpillar *Spodoptera littoralis* by the parasitoid *Microplitis rufiventris* is less at 27°C (80.6°F) than at 20°C (68°F) (Thomas and Blanford 2003). Natural enemies of the spruce budworm, *Choristoneura fumiferana*, are less effective at higher temperatures (Harrington *et al.* 2001).

Effect on honey bee: Global warming has direct influence on honey bee behavior and physiology. It can alter the quality and quantity of the floral environment and reduces colony harvesting capacity and development.

The bee, *Apis mellifera sahariensis* is found in the Sahara, where it has adapted to extreme heat. The survival requirement for these bees is a supply of water, which they use in large quantities to raise their larvae and to regulate the brood temperature to between 34°C and 35°C. In warmer environment, flowers are unable to provide enough water for bees and they die. According to climate change predictions, some regions will become even drier, leading to the disappearance of bee food and their honey bees. (Conte and Navajas, 2008). With respect to the potential effects of

future global warming, bees responses to avoid extreme temperatures have the potential to significantly reduce pollination services (Corbet *et al.* 1993).

Effect on mosquito: The predicted warmer summers and milder winter temperatures will favor mosquito development and extend the biting season of some species. Warmer climate could however reduce possible aquatic sites. Mosquitoes will adapt new breeding habitats. In such condition increased use of water by households is likely to increase the number of biting and non-human biting species around homes. It was also observed that higher temperatures lead to more rapid development of dangerous pathogens within insect carriers. For Example, transmission of malaria requires temperatures greater than 16°C (60.8°F), and a 5°C (9°F) increase in temperature doubles the growth rate of the *Falciparum* protozoa that causes malaria.

Effect on insect coloration: Insect coloration is the phenomenon of adoption to maintain the heat. Basically darker colors are employed to absorb the heat and paler colors to avoid or reduce the heating. Black reflects no light, so it retains a whole bunch of heat energy, which is great in a cold climate, but not so much in the global greenhouse. Scientists have noticed that warming climate is changing ladybugs of the coast of Netherlands from black to red. Red reflects more energy hence ladybugs stay cool. The difference between red and black in ladybugs is only one protein, so as far as genetic adaptations concerns, it's an easy switch.

Climate change may affect our abilities to manage pests: The increased number of generations per year and frequent population outbreaks of potential insect pests necessitate continual applications of high amount of insecticides and

that will make the insects to develop resistance against these chemicals (Petzoldt and Seaman, 2007). Global warming will also reduce the effectiveness of host plant resistance, transgenic plants, natural enemies, biopesticides, and synthetic chemicals for pest management (Sharma, 2010). Climate change may also indirectly affect insect herbivores; for example, excessive heat or drought create stress on trees and lower their defense, making them less resistant to insect attacks (Ayres, 1993). Casteel *et al.* (2009) reported that global warming could cause another deleterious effect in the form of deactivation of some genes responsible for the production of volatile substances that are used by plants to attract the natural enemies of the herbivorous insects. Vuorinen *et al.*, (2004) reported that, in cabbage elevated CO₂ level decreased the emission of Jasmonic acid regulated terpene volatiles that reduced the searching efficiency of the parasitoid, *Cotesia plutellae*.

CONCLUSION

Global warming is the international problem. Agricultural business is likely to suffer losses in long run due to climate change and new emerging pest scenario. Global warming and increased variability require improved analyses that can be used to assess the benefit/risk of the existing and the newly developed pest management strategies and techniques. IPM principles will be required to be followed more strictly in the future scenario of global warming. Reduction in use of pesticides will also help in reducing carbon emissions. Historical data should be taken into consideration while formulating the experiments and standardization of protocols. There are still many unknowns facts in our understanding related to the detrimental and beneficial effects of climate change to biological systems.

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