Impact of Climate Change on Insects

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The term global change embraces a range of natural and anthropogenic environmental changes. According to Intergovernmental Panel on Climate Change, it is defined as "Change in climate over time, either due to natural variability or as a result of human activity". Most of the warming observed over the last 50 years is attributable to human activities. The global mean surface temperature is predicted to increase by 1.4 to 5.8°C from 1990 to 2100. If temperatures rise by about 2°C over the next 100 years, negative effects of global warming would begin to extend to most regions of the world (IPCC, 2001). Such changes in climate and weather could profoundly affect the status of insect pests of crops. These may arise not only as a result of direct effects on the distribution and abundance of pest populations but also indirect effects on the pests' host plants, competitors and natural enemies (Porter, *et al.*, 1991). Some pests which are already present but only occur in small areas, or at low densities may be able to exploit the changing conditions by spreading more widely and reaching damaging population densities (Porter, *et al.*, 1991 and Bale, *et al.*, 2002). Keeping these facts in view, the topic on the impact of climate change on insects is discussed here.

Effects of Climate change on insects:

1. Insects are good indicators of current human driven climate change. They have responded to warming in all predicted ways from changes in phenology and distribution to undergoing evolutionary changes. Insects are among the groups of organism most likely to be affected by climate change because climate has a strong direct influence on their development, reproduction and survival. Moreover, insects have short generations times and high reproductive rates, so they can more like to respond quicker to climate change than long-lived organisms, such as plants and vertebrates (Menendez, 2007). Increasing climatic variability reduced the level of parasitism of caterpillars, which in turns may increase the frequency and intensity of herbivory outbreaks (Stireman, *et al.*, 2005).

Impact on arthropods diversity and extinction:

2. The current extinction rates are 100 to 1,000 times greater than what has happened earlier and nearly 45 to 275 species are becoming extinct everyday. It has been intimated that six degree increase in temperature will lead to the mass extinction of species including humans (Anonymous, 2013).

Impact on geographical distribution and population dynamics of insects:

Overwintering of insects will increase as a result of climate change, producing larger spring populations in the following season. These may be vulnerable to parasitoids and predators if the latter also overwinter more readily. There may also be increased dispersal of airborne insects in response to atmospheric disturbances. Many insects such as *Helicoverpa* sp. are migratory and therefore may be well adapted to exploit new opportunities by moving rapidly into new areas as a result of climate change (Sharma, 2005).

Impact on expression of resistance of plants to insect pests:

Global warming may result on breakdown of resistance to certain insect pests. Sorghum varieties exhibiting resistance to sorghum midge, *Stenodiplosis sorghicola* (Coq.) in India became susceptible to the pest under high humidity and moderate temperatures near the Equator in Kenya (Sharma, *et al.*, 1999). Lower foliar nitrogen content due to CO_2 causes an increase in food consumption by the herbivores up to 40%, while unusually severe drought increases the damage by insect species such as stem borer, *Chilo partellus* (Swinhoe) in sorghum (Sharma, *et al.*, 2005). Global warming may also change the flowering times in temperate regions, leading to ecological consequences such as introduction of new insect pests and attaining of a pest status by non- insect pests (Willis, *et al.*, 2008).

Impact on effectiveness of transgenic crops for pest management:

Possible causes for the failure of insect control in transgenic crops may be due to inadequate production of the toxin protein, effect of environment on transgene expression, *Bt*-resistant insect populations and development of resistance due to inadequate management (Sharma and Ortiz, 2000). *Cry1Ac* levels in transgenic plants decrease with the plant age, resulting in greater susceptibility of the crop to insect pests during the latter stage of crop growth (Kranthi, *et al.*, 2005).

Impact on effectiveness of insecticides:

Biopesticides and synthetic insecticides are highly sensitive to environment. Increase in temperature and UV radiation and decrease in relative humidity may render many of these control tactics to be less effective and such an effect will be more pronounced on natural plant products and biopesticides (Isman, 1997).

Impact of different parameters of climate change on insects:

Temperature:

Climate change resulting in increased temperature could impact crop pest populations in several ways. Most researchers seems to agree that warmer temperatures in temperate climates will results in more types and higher populations of insects. Researchers have shown that increased temperature can potentially affects insect survival, development, geographic range and population size. It can impact on physiology and development directly or indirectly through the physiology or existence of hosts. Some insects take several years to complete one life-cycle- (cicadas) will tend to moderate temperature variability over course of their life history. Some pests are ‘stop and go’ developers in relation to temperature. They develop more rapidly during periods of time with suitable temperatures. Increased temperature will accelerates the development of these types of insects-possibly resulting in more generations and crop damage per year. The potato tuber worm incidence under climate changes showed that the population of the pest at Ismalia gave the highest number of generations as compared with EL Beheira location under current climate. Generation numbers of tuber worm under climate change conditions increased especially in Ismailia location. However, the expected generation numbers of the tuber worm in 2050 and 2100 are expected to be 9 to 11 and 10 to 12 generations per year, respectively. This concluds that higher temperature in the future may thus increase the damage on crops, by increasing the number of generations of the pest (Abolmaaty, *et al.*, 2011).

The influence of temperature on the developmental times and survival of argentine ant, *Linepithema humile* Mayr (Hymenoptera: Formicidae) can largely determine their distribution. Temperature affects both the complete brood development from egg to adult worker and each of the immature stages separately. Higher the temperature, shorter the development times. Brood survival from egg to adult was low, with the maximum survival rate being only 16% at 26º C. Temperature also affected survival of each of the immature stages differently: eggs were negatively affected by high temperatures, while larvae negatively affected by low temperatures, and the survival of pupae was apparently independent of environmental temperature. At 32º C, no eggs survived, while at 18º C less than 2% of the eggs hatched into larvae. The data of the study are essential for developing prediction models about the distribution range of this tramp species based on its physiological needs in relation to temperature (Abril, *et al.*, 2008).

Elevated temperature decreased final plant biomass while leaf nitrogen concentration increased. Aphid, *Myzus persicae* Sulz. abundance was enhanced by both CO_2 and temperature treatment. Parasitism rated remained unchanged in elevated CO_2, but showed an increasing trend in conditions of elevated temperature. It shows that *M. persicae* might increase its abundance under changing climatic conditions (Bezemer, *et al.*, 1998).

Many insects are contributors to global warming because of the CO_2 they emit. Bug and termites is major contributor of global warming. With every degree the global temperature rise, the life cycle of each bug will be shorter. The quicker the life cycle, the higher will be the population of pests (Deka, *et al.*, 2012).

Carbon dioxide (CO_2) :

Generally CO_2 impacts on insects are thought to be indirect-impact on damage results from changes in the host crop. During the early season, soyabean grown in elevated CO_2 atmosphere had 57 % more damage from insects (primarily Japanese beetls, potato leafhopper, western corn rootworm and Mexican bean beetle) than those grown in today's atmosphere. It is thought that measured increase in the levels of simple sugars in the soyabean leaves may have stimulated the additional insect feeding (Hamilton, *et al.*, 2005).

Larval life-span of *Helicoverpa armigera* (Hubner) increased by 5.49, 7.02 and 10.26 % and larval survival rate decreased by 7.35, 9.52 and 11.48 % in first, second and third generations, respectively under elevated CO_2 compared with ambient CO_2. Consumption and frass per larva of bollworm fed on cotton bolls showed significant increase for the first, second and third generations under elevated CO_2. Significantly lower relative growth rate was observed in the first, second and third generations (Gang, *et al.*, 2007). Brachypterous females laid more eggs on rice plants exposed to elevated than ambient CO_2. Elevated CO_2 exhibited positive effect on BPH multiplication and resulted in more than a doubling of its population at peak incidence compared to ambient CO_2 (Prasannakumar, *et al.*, 2012).

The lifespan of *H. armigera* was delayed and larvae fed more artificial diet and produced more frass under elevated CO_2 compared with those under ambient CO_2. Furthermore, elevated CO_2 marginally influenced the artificial diet-utilization effciency of *H. armigera* larvae that decreased in relative growth rate (RGR), relative consumption rate (RCR), effciency of conversion of ingested food (Wu, *et al.*, 2006a).

The direct effects of elevated CO_2 on multiple generations of cotton aphid, *Aphis gossypii* were weak, even no existing. Moreover, the impact of elevated CO_2 level on the growth, development and fecundity of *A. gossypii* was mainly indirect, even though the host plants growing under elevated CO_2 levels were directly affected (Chen, *et al.*, 2005).

Longer larval life-span for the third generation and lower pupal weight for all generations were observed in *H. armigera* fed on milky grains of spring wheat grown in elevated CO_2. Moreover, the consumption, frass per *H. armigera* larva and RCR significantly increased under elevated CO_2 compared to ambient CO_2 (Wu, *et al.*, 2006b).

Precipitation/drought:

Large scale changes in rainfall will have a major effect on the abundance and diversity of arthropods. Analysis of precipitation data over the past 100 years showed that the total precipitation did not change, but the frequency of light rain decreased and the frequency of heavy rainfall increased (Das *et al.*, 2011). Some insects e.g. onion thrips are sensitive to precipitation and are killed or removed from crops by heavy rains (Reiners and Petzoldt, 2005). For some insects that overwinter in soil, flooding the soil has been used as a control measures (Vincent *et al.*, 2003). Decreasing snowfall promotes the expansion of pine moth, *Thaumetopoea pityocampa* into high elevation stands of mountain pine. More than 50 species of butterflies showed northward range expansions and 10 species of previously migrant butterflies have been established on Nansei Islands during 1966 to 1987. Droughts are likely to decrease multi-trophic diversity and change the composition of arthropod communities which in turn might affect the other associated taxa. Enhanced summer rainfall and drought conditions promote rapid increase in the population of wireworm (*Agriotes lineatus*) in the upper soil. Drought conditions severely affect egg viability of *Scopelosaurus lepidus* eggs and did not hatch at all under dry conditions (Karuppaiah and Sujiyanad 2012).

Temperature is the most important factor which limits the distribution, rate of development, number of generations and population abundance of an insect species in a region. Climate changes have adverse effects on host plant resistance, transgenic plants, natural enemies, biopesticides and synthetic chemicals used in pest management. Climate change alters the interactions between the insect pests and their host plants. As a result, some of the cultivars that are resistant to specific insect may become susceptible. Adverse effects of climate change on the activity and effectiveness of natural enemies will be a major concern in future pest management programmes. Rate of insect multiplication might increase with an increase in CO_2 and temperature. Therefore, there is a need to look the effects of climate change on crop protection and devise appropriate measures to mitigate the effects of climate change on food security.

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