Effects of Climate Change on Natural Control of Insect Pests

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ABSTRACT:
Natural enemies of insects are likely to undergo diverse effects due to changes in atmospheric CO₂ levels, increase in temperatures and shifts in precipitation. Plants respond to elevated levels of CO₂ with higher biomass. As a result there would be a dilution effect on nitrogen levels and those chemical constituents that require nitrogen. Lower nutritional value of plants adversely impacts insects that feed on them directly and also their parasitoids and predators indirectly. Increased temperatures can alter both plant and herbivore phenology with likely impact on synchronization between the two again indirectly influencing the activity of natural enemies and the effectiveness of their natural control. Hymenopteran wasp parasitoids which are relatively host-specific are likely to be influenced more than tachnid flies which generally survive by feeding on a variety of insects. Higher minimum temperatures in temperate regions can lead to expansion of geographical range of insect pests which are currently intolerant to low temperatures. This may result in pest outbreaks in the newer areas if natural enemies fail to track and follow their hosts. Variability in rainfall reportedly has an adverse influence on parasitism levels of several caterpillar pests. Sucking pests like cereal aphids are less susceptible to climate change effects.
In case of mealybugs, parasitism is reduced under conditions of water stress associated with drought conditions apparently due to improved immune response. The effects of climate change on natural enemies mediated by CO$_2$ temperature and moisture effects on plants could be complex and unlikely to be predicted easily due to interactions between these effects. Adaptation and mitigation practices to combat climate change such as conservation agriculture practices are likely to have a positive effect on parasitoid and predator abundance with resultant benefits on natural pest control. Much of the climate change research has been conducted in the temperate countries. While referring to these available results, an attempt has been made in this review to illustrate examples of natural regulation of insect pests in India in the context of climate change and variability.

**Key Words:** Climate change, climatic variability, effects, herbivores, natural enemies, parasitoids, predators, natural control, natural regulation

**Introduction**

Elevated atmospheric CO$_2$ levels, increased temperatures and shifts in precipitation effect the interactions between plants, insect herbivores and natural enemies in diverse ways that are difficult both to understand and predict. Quite a few studies have been carried out on the direct effects of climate change on plant species which are at the first trophic level (Long *et al.*, 2004). While effect on insect herbivores has received research attention in recent years (Trnka *et al.*, 2007) very few studies have been devoted to elucidate the effects on the third trophic level comprising of parasitoids and predators.

Two approaches to elicit climate change effects are evident from literature. One approach has been to apply mathematical models to predict the response of specific groups of natural enemies to climate change (Stireman *et al.*, 2005; Guiterrez *et al.*, 2008). The other approach aims at providing empirical evidences involving all the three trophic levels: plant-herbivore-natural enemy and have come mainly from experiments that demonstrated the responses to individual climate change parameters, either elevated CO$_2$ or temperature (Bezemer *et al.*, 1998).

Abrupt environmental changes as induced by current climatic variability are likely to exert greater influence on pests and natural enemies than the gradual climate change. When pests and natural enemies in the trophic system react differently to the climatic conditions, this can lead to ecological imbalances and disruptions (Hance *et al.*, 2007). When it comes to the case of natural enemies, climate change effects could be different for parasitoids and predators. Again among parasitoids, many hymenopteran wasp parasitoids which are relatively host-specific and are considered as specialists are more sensitive to changes in their host emergence times or developmental rates than tachnid flies which feed on several host insects and are likely to be less susceptible to the asynchrony with their hosts induced by climate change.

Recent reviews have summarized the effects of climate change on parasitoids and all kinds of natural enemies of agricultural pests (Thomson *et al.*, 2009). This review focuses on the effects of climate change and variability on insect natural enemies of pests, parasitoids and predators, highlighting their responses to elevated CO$_2$ and temperature, and shifts in precipitation. Insect pathogenic viruses, fungi, protozoa and bacteria which are also natural enemies of insect pests are not covered in this review. With reference to the Indian context, natural enemies render valuable ecosystem services by naturally regulating insect pest populations particularly in dryland crops grown under resource poor environments where pesticide use is minimal. The important role of natural regulation is illustrated with two examples. The first one is the recent widespread occurrence of the mealybug species, *Phenacoccus solenopsis* Tinsley on Bt-cotton in India and its regulation by the dominant native parasitoid, *Aenasius bambawalei* Hayat. Another example of excellent natural control is of the invasive pest species, spiraling whitefly by two exotic parasitoids that came along with the pest. Also, crop-pest-natural enemy systems that warrant a closer watch in the near future vis-à-vis observed climatic variability at selected locations have been presented.
**Effects of increased atmospheric CO$_2$ levels**

Direct effects of CO$_2$ concentrations on insects have not been much investigated. Increased atmospheric CO$_2$ levels have an indirect influence on natural enemy fitness with the effects mediated by changes brought about in plants and their herbivore hosts. Many plant species respond to enriched atmospheric CO$_2$ by enhanced photosynthetic rates and increase in biomass. Also, plants have reduced nutritional levels for insect herbivores including decreased nitrogen leading to their increased plant consumption rates (Bezemer et al., 1998). This can result in an increased level of plant damage because the pests have to consume more plant tissue to acquire similar levels of nutrition especially in foliage feeders (Srinivasa Rao, et al., 2009), which is known as compensatory feeding. Other plant mediated effects on phytophagous insects include slow development, reduced fecundity and increased mortality (Watt et al., 1995).

Yin et al. (2009) conducted an experiment under 750 ppm CO$_2$ concentration involving *Helicoverpa armigera* Hubner larvae reared on milky grains of wheat and its larval parasitoid *Microplitis mediator*, widely used in its biocontrol. No significant change in parasitisation rate of *M. mediator* was found. The development of the parasitoid wasp, *Glyptapanteles liparidis*, of gypsy moth, *Lymantria dispar*, feeding on three different tree species fumigated with 540±20 ppm CO$_2$ was not adversely affected by changes in food quality when compared to ambient CO$_2$ (Schafellner and Schopf, 2008).

Coll and Hughes (2008) investigated the effects of elevated CO$_2$ on *H. armigera* and an omnivorous bug, *Oecalia schellenbergii*, Guerin-Meneville which not only feeds on plants but also preys on the bollworm. Bollworm larvae feeding on elevated CO$_2$-grown pea plants, *Pisum sativum* at 700 ppm were significantly smaller than those reared on plants grown under ambient-CO$_2$ conditions. The omnivorous bug required prey to complete its development, and performed best on a mixed plant-prey diet, regardless of CO$_2$ level. The bugs performed best when fed with larvae from the elevated-CO$_2$ treatment apparently because these prey were smaller and thus easier to overcome. Taken together, results indicate that elevated CO$_2$ may benefit generalist predators through increased prey vulnerability, which means that pest species are likely to be under higher risk of predation.

The effects of elevated CO$_2$ on natural enemies are essentially indirect and mediated through changes in herbivore hosts that feed on plants with altered nutritional quality. The effects are mainly reflected in the form of changes in natural enemy fitness, development, mortality and abundance, and differ between parasitoids and predators. Within the parasitoid category, the specialists that are host-specific are likely to be more adversely affected than generalists that survive on a variety of host insects. Very few research experiments have been conducted under controlled conditions with elevated CO$_2$ to investigate the effects on tritrophic systems.

**Effects of increased temperature**

Temperature greatly influences the survival, development and abundance of insects and the effect is direct. Each insect species and even each population might have different optimum temperatures for survival and reproduction. Insects inhabiting the colder climates with marked seasons have better tolerance to thermal extremes. They are currently exposed to cooler temperatures than their optima (Deutsch et al., 2008) and therefore might benefit from global warming. An increase of 3°C in mean daily temperature would cause the carrot fly, *Delia radicum* (L.) to become active a month earlier than at present (Collier et al., 1991). An increase of 2°C will reduce the generation turnover of the aphid, *Rhopalosiphum padi* (L.) (Morgan, 1996).

Several effects have been reported as a result of a warmer climate in the colder regions including changes in geographical distribution of pests, increased survival in overwintering populations, advancement of emergence times, arrival patterns, changes in population growth rates, increase in number of generations, extension of development season, changes in crop-pest synchrony, and changes in inter-specific interactions. Insects inhabiting the tropical regions are already living at environmental temperatures close to their optimum and any further increase will have adverse effects. With reference to natural enemies, research on the effects of climate change under controlled conditions is limited.
to a few studies involving elevated temperature. Many of the inferences are from field observations recorded over a number of years in diverse environments.

The most significant consequence of rising temperatures is the change in distribution in range of crops, pests and their natural enemies. Insect pests that have greater mobility are likely to track the expansion in crop ranges as minimum temperature rather than maximum temperature plays an important role in determining global distribution of pest species (Hill, 1987). For example, warming will allow the pink bollworm, *Pectinophora gossypiella* (Saunders) to expand its range on cotton into areas that are at present not congenial (Guiterrez *et al.*, 2008). There are many such examples of marked changes in the distribution in the northern hemisphere in response to unusually hot summers (Parmesan *et al.*, 1999). It is predicted that a 1°C rise in temperature would enable species to spread 200 km northwards or 140 m upwards in altitude (Parry *et al.*, 1989). The most crucial factors in the higher latitudes for population buildup and shift in pest intensity include higher survival rate of overwintering populations. Global warming might therefore benefit many insect species in the temperate regions. Crop, pest and natural enemy shifts into newer areas are more likely in the northern latitudes than in the tropics (Neumeister, 2010).

Even in the tropics, *Helicoverpa* spp. are migratory and therefore may well be adapted to exploit new areas in the higher latitudes (Sharma, 2005).

Range expansion over large distances is often exhibited by invasive pest species (Porter *et al.*, 1991). In such a scenario, the invasive pest generally lacks native specialist parasitoids unless they have moved along with the pest. Unlike the case of invasive species, range expansion of other pests attributed to climate change will most often be incremental and therefore natural enemies might be able to track their hosts depending on their movement rates.

All species will be under strong selection pressures, which may be different from those exerted when the climate is stable. Natural enemies are no exception. Exposure to temperature extremes even for short periods is likely to influence parasitoid survival and host searching ability (Scott *et al.*, 1997). Temperature influenced the fecundity and sex ratio of *Campoletis chloridea*, an ichneumonid larval parasitoid of *H. armigera* (Dhillon and Sharma, 2009). Short exposure to higher temperatures can eliminate endosymbiont bacteria like *Wolbachia* and *Buchnera* which influence several aspects of parasitoid reproduction (Thomas and Blanford, 2003).

Fluctuations in parasitoid abundance and observed wide ranges in field parasitisation levels may be attributed to climatic conditions. In case of predators, however, it could be different. For example, it has been predicted that coccinellids reduce aphids more strongly in hot summers than in moderate summers (Skirvin *et al.*, 1997). Overall, there is lack of a clear understanding of the dynamics of matching thermal requirements of parasitoids, predators and their hosts as a tritrophic system. It is generally perceived that natural enemies are relatively more sensitive to climatic variability than their herbivore hosts. Perhaps this is explained by higher intrinsic rates of population increases following decimation by herbivores relative to natural enemies (Thomson *et al.*, 2010). Each species has to be analyzed separately to understand and predict the influence of either gradual or abrupt increase in temperatures (Table 1).

**Interaction effects of elevated CO₂, temperature and shifts in precipitation**

The host plant mediated adverse effects of elevated CO₂ on insect herbivores and their natural enemies could be moderated when experiments were conducted under a combination of increased CO₂ and temperature conditions (Zvevera and Kozlov, 2006). Changes in precipitation are also of greater importance in agriculture especially in regions where lack of rainfall may be a limiting factor for crop production (Parry, 1990). Stireman *et al.*, (2005) analyzed the frequency of parasitism in 15 Lepidoptera rearing programs from a broad spectrum of climatic regimes and locations located between southern Canada and central Brazil. The meta analysis indicated that the variability in precipitation was a key factor influencing parasitism. A higher variability in rainfall led to a decrease in parasitism. These findings basically support the generalization that interactions which have evolved over stable conditions are weakened when frequent changes occur.
The combined effects of temperature, CO₂ and nutrition levels might not be easily predicted because of interaction of these effects. This has been evident in the case of models depicting the interaction between grasses, cereal aphids and their natural enemies (Hoover and Newman, 2004). In this system, changes in CO₂ and higher temperatures affected plant growth but only temperatures altered developmental rate of the aphid hosts and their parasitoids. This resulted in a limited impact of increased CO₂ and temperature combination on the aphid population and also a limited impact of parasitoids on the aphid population.

There are other ways that plant responses to climate change can influence herbivores and their control through natural enemies. Under conditions of water stress associated with drought conditions parasitism of mealybugs on cassava was reduced (Calatayud et al., 2002). This has been attributed to improvement in immune response of mealybugs growing on water stressed plants, leading to an increased rate of encapsulation ranging from 30-50% in three different species of encyrtid mealybug parasitoids. Studies carried out till now indicate that the interactive effects of changes in CO₂, temperature and rainfall on natural enemies can be complex and hence it is difficult to predict their combined effects.

**Effect of climate change adaptation practices on natural enemies**

Adaptation and mitigation practices to combat climate change and its variability such as increasing crop diversity on farms, reduced tillage, use of mulches, increasing vegetation diversity both on farms and landscapes are likely to influence the abundance of insect pests and their natural enemies. Positive effects

### Table 1: Influence of temperature changes on natural enemies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nature of effect</th>
<th>Natural enemy</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>Reduced when exposed to abrupt change</td>
<td>Egg parasitoid, <em>Trichogramma carverae</em> Oatman and Pinto</td>
<td>Scott et al., 1997</td>
</tr>
<tr>
<td></td>
<td>Reduced at lower (&lt;12°C) and higher temperatures (&gt;35°C)</td>
<td><em>Campoletis chlorideae</em> Uchida on chickpea pod borer, <em>Helicoverpa armigera</em></td>
<td>Dhillon and Sharma, 2009</td>
</tr>
<tr>
<td>Distribution range</td>
<td>Lower mortality of herbivore due to escape from parasitoids in the expanded range</td>
<td>Parasitoids of Argus butterfly, <em>Aricia agestis</em> Dennis &amp; Schiffermuller</td>
<td>Menendez et al., 2008</td>
</tr>
<tr>
<td>Host searching ability</td>
<td>Decreased at higher temperatures</td>
<td>Egg parasitoid, <em>T. carverae</em></td>
<td>Thomson et al., 2001</td>
</tr>
<tr>
<td>Fecundity</td>
<td>Reduced at temperatures above threshold (&gt;35°C)</td>
<td>Egg parasitoids, <em>T. pretiosum</em> Riley and <em>Trichogrammatoidea bactrae</em> Nagaraja</td>
<td>Naranjo, 1993</td>
</tr>
<tr>
<td>Diapause</td>
<td>Prevention of diapause induction due to changes in day length and temperature</td>
<td>Coccinellid predator, <em>Harmonia axyridis</em></td>
<td>Soares et al., 2008</td>
</tr>
<tr>
<td>Phenological asynchrony</td>
<td>Poor synchronization in emergence time between parasitoid and its host</td>
<td>Leaf miner parasitoids</td>
<td>Grabenweger et al., 2007</td>
</tr>
<tr>
<td>Natural / Biological control</td>
<td>Poor parasitisation during hot and dry weather</td>
<td>Egg parasitoid, <em>Trichogramma</em> on borer, <em>Ostrinia nubulalis</em></td>
<td>Cagan et al, 1998</td>
</tr>
</tbody>
</table>
on parasitoid and predator abundance and diversity are likely with resultant benefits on increased natural regulation of pests (Table 2), sustainable crop production and mitigation of climate change (Thomson et al., 2010).

**The Indian context**

Relatively less warming is expected in the tropics than at the higher latitudes in the northern hemisphere (Sutherst, 1991) where the rate of increase projected is about 0.1°C for each degree of latitude. By 2040, India is likely to experience an increase in the annual mean surface air temperatures of 1.0°C over land regions (Lal et al., 1995). Warming in the tropics is likely to be within the temperature optima of native pests and natural enemies. Between seasons, warming in the rainy season will be less pronounced than in the winter months over the region. However, rainfall is predicted to be highly erratic with fewer rainy days but with greater intensity. A combination of higher average annual temperatures and water excess or deficit can have serious implications. The frequency of occurrences of extreme weather events such as drought, floods, heat wave, cold wave, unusual and unseasonal rainfall, cyclones, frost and hailstorm is on the rise in recent years than in the past. Effects on insect pests and their natural enemies have been manifold as a response to increase in temperatures and changes in rainfall. Distribution of insect pests is likely to be influenced by changes in the cropping pattern triggered by climate change. Major insect pests such as cereal stem borers (*Chilo, Sesamia*, and *Scirpophaga*), the pod borers (*Helicoverpa*,

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**Table 2**: Effect of climate change adaptation and mitigation practices on natural enemies

<table>
<thead>
<tr>
<th>Adaptation and mitigation practices</th>
<th>Effect on pests and natural enemies</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased crop diversity on farms through intercropping / mixed cropping / strip cropping</td>
<td>Increased egg parasitisation of <em>H. armigera</em> Transfer of parasites from sorghum to short- and medium duration pigeonpea</td>
<td>Romies et al., 1999 Duffield and Reddy, 1999</td>
</tr>
<tr>
<td>Pigeonpea + Sorghum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigeonpea + Greengram/ Sorghum / Groundnut</td>
<td>Increased abundance of coccinellid predators and spiders</td>
<td>Srinivasa Rao et al., 2003</td>
</tr>
<tr>
<td>Cotton + Groundnut/ Soybean/ Cowpea/ Greengram</td>
<td>Low incidence of <em>H. armigera</em>, positive effect on natural enemies</td>
<td>Venugopal Rao et al., 1995</td>
</tr>
<tr>
<td>Cotton + Clusterbean or Greengram</td>
<td>Low incidence of leaf hoppers, aphids, thrips and whiteflies; higher populations of predators</td>
<td>Balasubramanian et al., 1998</td>
</tr>
<tr>
<td>Increased field border diversity and remnant vegetation</td>
<td>Increased abundance and diversity of natural enemies on many crops</td>
<td>Gurr et al., 2003; Olson and Wackers, 2007</td>
</tr>
<tr>
<td>Conservation agricultural practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero till or low tillage plantings &amp; Mulches with crop residues</td>
<td>Increased abundance of Hymenopteran parasitoids; Dipteran parasitoids and predators; and Hemiptera predators in vineyards</td>
<td>Thomson and Hoffmann, 2007</td>
</tr>
<tr>
<td></td>
<td>Increased parasitisation and predation of cereal aphids</td>
<td>Schmidt et al., 2004</td>
</tr>
<tr>
<td>Re-vegetation of agricultural landscapes</td>
<td>Increased abundance of carabid predator Long-term conservation of natural enemies in agro-ecosystems</td>
<td>Nash et al., 2008 Tscharntke et al., 2007</td>
</tr>
</tbody>
</table>
Maruca, and Spodoptera), aphids and whiteflies may move to temperate regions, leading to greater damage in cereals, grain legumes, vegetables, and fruit crops (Sharma, 2010). Some of the changes evident are shifts in pest status, increasing menace of invasive alien species and wide fluctuations in natural enemy activity. Earlier than normal infestations of Helicoverpa armigera (Hub.) are likely in North India due to rise in temperatures (Sharma, 2010) resulting in increased crop loss in pigeonpea and chickpea.

In the recent years, threat to Indian agriculture has come from instances of invasion by alien insect species, all of which are sucking pests viz., papaya mealybug, wooly aphid in sugarcane, coconut mite and spiraling whitely in many plantation and orchard crops. Among the native species, increased flare ups of sucking pests such as jassids and whitefly in cotton and thrips as virus vectors in groundnut, sunflower and tomato have been noticed. In some way these changes in pest distribution and outbreaks are connected to climate change and climatic variability which need to be understood. Two cases in which dreaded pest species have been regulated successfully by natural enemies, one example of a native parasitoid and another case of accidental introduction of the natural enemies along with the invasive pest are illustrated.

The case of natural regulation of the solenopsis mealybug

The mealybug species, Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) has been reported on cotton (Gossypium hirsutum L.) in Pakistan and India causing severe economic losses in the initial years. Infestations have broken out suddenly and spread rapidly to all the cotton growing zones in the country. Wang et al. (2010) analyzed seasonal and annual population growth data of P. solenopsis from nine locations in its native range in the U.S.A., and the distribution of the mealybug worldwide using the CLIMEX model. The analysis indicated that tropical regions worldwide were highly suitable for P. solenopsis. Its potential distribution was limited by cold in higher latitudes and altitudes, and dryness in northern Africa, inland Australia and parts of the Middle East. CLIMEX was used to predict where P. solenopsis might establish, and to estimate the potential threat to cotton yield in Asia. The key limiting factors were low precipitation as well as minimum temperatures in northern areas. When irrigation was factored into the simulation, the potential distribution of P. solenopsis expanded dramatically, indicating that the mealybug presents a great economic threat to cotton in Asia.

In India, the mealybug was noticed in 2006 in the north zone comprising of Punjab, Haryana, Rajasthan and Gujarat (Nagrare et al., 2009). Its occurrence has been reported from the Central cotton growing zone and was observed at a perceptible level during 2008 in Andhra Pradesh. The pest attacks growing parts and results in bumpy and stunted growth of the affected plants which produce small sized bolls with bad opening. Estimated reduction in seed cotton yield due to the pest is about 44 percent (Dhawan et al., 2007). The pest has a wide host range that includes cultivated crops and weed flora in India (Vennila, 2011).

Solitary endoparasitoid, Aenasius bambawalei Hayat (Hymenoptera: Encyrtidae), has been reported on P. solenopsis (Hayat, 2009). Adult females parasitize third instar nymphs of P. solenopsis and kill the host before its maturity. Mealybug mummies formed due to parasitization are reddish brown and can easily be distinguished from the healthy colony. In the initial stages of pest establishment and rapid spread, extent of parasitoid activity was negligible. However, the parasitoid is active now in all the cotton growing zones of the country. We have recently documented the potential of A. bambawalei as a parasitoid on P. solenopsis not only on cotton, but on several alternate hosts which have a key role in the carryover of pest and its natural enemy, A. bambawalei. However, decline in severity of Phenacoccus mealybug incidence after the 2008 cotton season has been noticed in all the cotton growing regions (Fig 1). A. bambawalei is responsible for the decline of mealybug in the north zone after its initial unabated establishment (Rishi Kumar, et al., 2009).

The case of spiralling whitefly

The spiralling whitefly, Aleurodicus dispersus Russell, poses a threat to many crops in India. A.dispersus, native to Caribbean islands and Central America probably came to India either from Sri Lanka or the Maldives.
Fig. 1: Population dynamics of cotton mealybug at Sirsa, Haryana during 2008-2010 (Rishi Kumar - personal communication). Severity based on a rating scale of 1 to 4 (lowest and highest severity, respectively)

Table 3 : Trends in climatic variability at selected locations and crop-pest-natural enemy systems that warrant attention

<table>
<thead>
<tr>
<th>Location</th>
<th>Observed trend in climatic variability*</th>
<th>Crop</th>
<th>Insect pest</th>
<th>Natural enemy</th>
<th>Stage of insect attacked</th>
<th>Potential natural regulation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bijapur</td>
<td>Decrease in rainfall in September and October</td>
<td>Sorghum</td>
<td>Stem borer <em>Chilo partellus</em> Swinhoe</td>
<td><em>Trichogramma chilonis</em> Ishii,</td>
<td>Eggs</td>
<td>Up to 90</td>
</tr>
<tr>
<td>Mahabubnagar</td>
<td>Increase in rainfall variability</td>
<td>Castor</td>
<td>Semilooper <em>Achaea janata</em> Linnaeus</td>
<td><em>Trichogramma chilonis</em> Ishii</td>
<td>Eggs</td>
<td>30-40</td>
</tr>
<tr>
<td>Akola</td>
<td>Decrease in rainfall in June to September, Low winter temperatures</td>
<td>Soybean</td>
<td>Leaf eating caterpillar <em>Spodoptera littura</em> Fabricius</td>
<td><em>Telenomus remus</em> Nixon <em>Cotesia flavipes</em> Cameron <em>Aenasius bambawalei</em> Hayat</td>
<td>Eggs</td>
<td>30-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cotton</td>
<td>Mealybug, <em>Phenococcus solenopsis</em> Tinssley</td>
<td></td>
<td>Larvae</td>
<td>30-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nymphs and Adults</td>
<td>40-50</td>
</tr>
<tr>
<td>Anand</td>
<td>Increase in temperatures, Increase in intense rainfall events (&gt;150mm)</td>
<td>Groundnut</td>
<td>Leaf miner <em>Aproaerema modicella</em> (Deventer) <em>S.litura</em></td>
<td><em>T. chilonis</em> <em>T. remus</em> <em>C.flavipes</em></td>
<td>Eggs</td>
<td>20-30</td>
</tr>
<tr>
<td>Faizabad and Kanpur</td>
<td>Erratic winter rainfall and increase in minimum temperatures</td>
<td>Chickpea, Pigeonpe</td>
<td>Pod borer <em>Helicoverpa armigera</em> (Hubner)</td>
<td><em>Compoletis chloridae</em> Uchida</td>
<td>Larvae</td>
<td>40-50</td>
</tr>
<tr>
<td>Jorhat</td>
<td>Decrease in August rainfall</td>
<td>Rice (rainfed)</td>
<td>Yellow stem borer <em>Scriopophaga incertulas</em> Walker</td>
<td><em>Tetrastichus</em> spp.</td>
<td>Egg mass</td>
<td>Up to 100</td>
</tr>
</tbody>
</table>

* Rao et al., 2010
In India, it was first reported in 1993 at Thiruvananthapuram on tapioca and from several other parts of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra. The pest is highly polyphagous infesting about 280 plant species in India. Among them highly preferred dryland field crops are groundnut, castor, cotton and fruit crops are guava and custard apple. Eggs are laid in a typical spiral pattern from which the whitefly derives its common name. Nymphs and adults suck the sap from the leaves causing damage to several crops in peninsular India. In the affected regions, heavy sporadic rains and cool temperatures resulted in a temporary reduction in A. dispersus population. The population of spiralling whitefly is found to be relatively higher during summer months and the density of the whitefly is positively correlated with maximum temperature and negatively correlated with relative humidity. Survey has revealed the presence of 45 predators and two parasitoids namely Encarsia guadeloupae Viggiani and Encarsia haitiensis Dozier. Both these accidentally introduced parasitoids are likely to cover all the spiralling whitefly areas and cause remarkable reduction in the population of A. dispersus in India as witnessed in other countries (Mani, 2010) unless this activity is disrupted by climatic variability which needs to be closely monitored.

Conclusions

1. Climate change and climatic variability can have diverse effects on natural enemies of pest species. A careful analysis is needed on how the host-natural enemy systems react to changes in temperature and CO₂. There is an urgent need to investigate the effects of both these climate change parameters separately and jointly under controlled environmental conditions to understand the nature and direction of their effects on natural enemies as part of the tritrophic system.

2. Available long-term historical field data records at regional and local scales need to be closely examined to elucidate the effects in terms of changes in pest-natural enemy distribution, mismatch in crop-pest-natural enemy synchronization, effects on fitness, abundance, inter- and intraspecific interactions.

3. In the tropics, especially in India, greater research attention is needed in view of the enormous diversity and complexity of the agro-ecosystems and landscapes to harness the full potential of natural enemies. Well planned and coordinated pest surveillance programmes such as those currently in operation in several states like Maharashtra, Orissa, Punjab and Gujarat are most relevant and timely. Monitoring of natural enemies and documenting the extent of natural regulation needs greater emphasis in such programmes.

4. Some of the observed trends in climatic variability at selected rainfed locations in India along with the vulnerable crop-pest-natural enemy systems are presented in Table 4. These and other identified tritrophic systems warrant greater research attention and need to be monitored closely in future.

5. Climate change effects the life-history traits of hosts and natural enemies differently. The effects could be more on natural enemies as they are at a higher trophic level. As a consequence the extent of natural or biological control is likely to be affected giving scope for pest outbreaks. Greater understanding of the diverse effects is only possible by studying the behavioural, physiological and functional adaptations of natural enemies to climate extremes both at the species level and at the community level. This can lead to development of appropriate adaptation strategies that maximize the extent of natural regulation of insect pests, particularly in dryland ecosystems which are fragile and are in greater need of such ecosystem services.

References


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