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Insect Response to Environmental Changes and Futuristic Pathway Studies

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Abstract. Environmental shifts, particularly global warming and altered land uses, increasingly influence the intricate relationships between insects and their diverse hosts. Insect species exhibit heterogeneous responses to these changes, contingent on their specific habitat and ecological niche. Numerous factors, including geographical range, diversity, abundance, growth, and development, are modulated by these environmental shifts, leading to both positive and negative effects on various insect populations. Consequently, the pervasive influence of climate change on the delicate equilibrium of insect populations and their critical ecological roles represents a significant area of ongoing academic research. This review synthesizes current observations regarding the multifaceted impact of climate change on insect biota, while also highlighting key knowledge gaps that need to be addressed to facilitate improved management strategies for the benefit of humankind.

1 Introduction

Environmental shifts driven by anthropogenic activities pose a significant challenge to the balance of global ecosystems. Over past century, human interference in agriculture though intensive cropping, high volume of fossils fluid combustion/utilization and erratic industrial planning particularly in developing and underdeveloped countries, play a key role in climate chances and global warming[1].
The resulting environmental alterations, including more frequent droughts, elevated atmospheric carbon dioxide (CO_2) concentrations, and disruptions to established weather patterns, present continuous and evolving challenges to insect biota. The human-caused activities ultimately shift the natural atmospheric balance of through high emission of various greenhouse gases, such as methene, carbon dioxide nitrous oxide and high chlorofluorocarbons. In these climatic shift insects showed diverse responses and the observation gave both increasing and decreasing trends in their abundance and distribution [2].
As with other organisms, insects are profoundly affected by these climatic shifts; for instance, a comprehensive survey of 1600 insect species identified and simple climate change impacts on 940 of them [3].

Consequently, assessing and predicting the impacts of climate change constitutes one of the most critical and intensive research endeavours within insect science [4].

Bulk of information's was generated in the subjects, how climate influences the insect's geographical distribution, ecology, behaviour, physiology, phenology, genetics, evolution. The results finally suggested that the abiotic factors such as temperature, carbon dioxide and humidity, directly shapes the insect physiology, behaviours, insect biology and its dynamics and overall host plants and natural enemies complex, which are responsible for crop growth and final yield [3]. Here it is necessary to underline that insect is a key component of ecosystem as they provide various ecosystem services such as pollination and as scavengers, and any alteration of their population significantly impacts the essential services that they play [5].

The ectothermic (cold-blooded) animals, insects are particularly sensitive to rising temperatures. For example, increased temperatures can accelerate insect development, enhance survival rates, and boost reproductive capacity, as evidenced by the expanded geographical range and improved winter survival of the pink bollworm, *Pectinophora gossypiella*, under warmer conditions . Conversely, extreme weather events, such as droughts and heavy rainfall, can

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indirectly impact insect populations by affecting their natural enemies, a phenomenon observed in the oriental armyworm, *Mythimna separata*.

Insect responses to various climate components

The multidimensional climatic disturbance to insects are sub divided in to six sub head by Musolin (2007): (1) shifts in geographical ranges, (2) changes in abundance, (3) alterations in phenology, (4) modifications in voltinism, (5) adaptations in morphology, physiology, and behavior, and (6) changes in interactions with other species and within ecological communities. A diverse array of research methodologies has been employed to investigate these responses.

While global climate typically undergoes very slow changes over geological timescales (thousands to millions of years), the current environment is experiencing unprecedented rapid alterations primarily due to human intervention. Therefore, understanding the factors governing past climate change and their historical effects on insects is crucial for predicting future impacts. This section highlights key climatic factors and their observed or potential effects on insect populations, discussed under subsequent subheadings.

1.1 The sun and cosmic rays

The Sun's energy output, while exhibiting daily fluctuations, exerts a significant long-term influence on Earth's climate. Over millennia, variations in the Earth's orbital parameters around the Sun and the tilt of its axis have profoundly affected the distribution of solar radiation across the planet. These astronomical variations, collectively known as Milankovitch cycles, directly impact seasonal temperature differences. Specifically, the Earth's axial tilt oscillates between 22.1° and 24.5° over an approximately 41,000-year cycle. A greater axial tilt leads to more pronounced seasonal variations, characterized by warmer summers and colder winters. Beyond direct radiation, the Sun also emits charged particles, forming the solar wind. Although Earth's magnetic field largely shields the planet from these particles, high-energy solar cosmic rays can still penetrate the atmosphere. The precise influence of solar activity, including cosmic ray flux, on terrestrial climate remains an active area of investigation, but it is hypothesized to affect both direct solar heating and cloud formation processes. Increased absorption of solar radiation contributes to rising surface temperatures, which, in turn, can accelerate the release of carbon dioxide (CO_2) from terrestrial soils, creating a positive feedback loop.

1.2 Human activities and the greenhouse effect

Un questionably, Human activities are the primary driver of the accelerated global warming observed over the past 50 years. The forecast of Intergovernmental Panel on Climate Change (IPCC) indicated that the global surface temperature between 1990 to 2100 with the increase of increases of 1.4 to 5.8^{0}C and the temperature rise in next century by 2^{0}C will be detrimental to ecosystem as well as for main kinds.

Since the pre-industrial era, atmospheric CO_2 levels have surged dramatically, from approximately 280 parts per million (ppm) to 401 ppm by 2015, as recorded at the Mauna Loa Observatory, Hawaii. The extensive combustion of fossil fuels, widespread deforestation, and various agricultural practices have significantly increased the concentrations of greenhouse gases in the atmosphere. This intensification of the greenhouse effect has led to a substantial warming of the planet. While human influence on climate was minimal in the distant past, the Industrial Revolution marked a crucial turning point, initiating a rapid and sustained rise in greenhouse gas emissions. In addition to greenhouse gases, aerosols also play a role in climate forcing. Black carbon, a type of aerosol, contributes to warming by absorbing both incoming solar radiation and outgoing terrestrial radiation. It also accelerates snow and ice melt by darkening the surface, reducing albedo. Conversely, other aerosols, such as sulphates and organic carbon, can exert a cooling effect by reflecting sunlight back into space. The complex interactions between clouds and these aerosols further influence climate by affecting cloud formation, dissipation, reflectivity, and precipitation patterns.

Climate change can regulate interactions between insects and their hosts

The population dynamics and community structure of insects are influenced by a complex interplay of major factors and processes, including climate, competition, resource limitation, natural enemies, and various trophic and non-trophic interactions (e.g., with microbial symbionts) [7]. Disentangling the intricate interactions among these factors and processes and subsequently determining their relative importance in shaping species distribution and abundance, represents a considerable scientific challenge that has been addressed in only a limited number of exceptional studies [8].

The global ecological impact observed using ecological niche models suggested a distinct mismatch between plants and herbivorous insects. These results further highlight that the species-specific response in any climatic change may change insect plant interaction and the tropic levels as in case of butterfly, *Boloria titania* (Esper) and its larval host plant, *Polygonum bistorta* (L.) [9].

Outbreaks of the climate-dependent psyllid, *Cardiaspina* sp., and their severe effects, leading to Eucalyptus dieback across thousands of hectares of Western Sydney's critically endangered Cumberland Plain Woodlands (CPW), have been attributed to changing temperatures. In 2013 summer when temperature exceeds more than 46^{0}C and food shortage because of leaf defoliation leads to an outbreak of *Cardiaspina* sp. and in subsequent year it was almost unnoticeable in CPW [10]. Contrarily in mid-2015 psyllid again appear and resulted heavy defoliation in large area of CPW until situation similar to 2013.

Climate change can also disrupt beneficial ecological relationships, potentially interrupting or even eradicating mutualistic interactions such as pollination and seed dispersal. A simulation base studies conducted [11] on 1419 pollinators and 429 plants species revealed that 17 to 50% pollinators experiences food shortages because of two-week phenological advancement. This reduction is even more pronounced for specialist pollinators.

Finally, on the basis of available literatures [12] provided an in-depth information on how climatic change divers affecting plants and plant herbivorous insects and plant pollinators interactions (Table 1),

Classifying and ranking the underlying factors and processes influencing outbreaks of different insect species and how ecosystems respond remains a significant challenge. This difficulty arises because ecosystems react in diverse ways at both individual and community levels under any given set of environmental conditions [13].

Table 1. Impact of global environmental change (GEC) drivers on plant chemical traits mediating plant–herbivore & plant–pollinator interactions (12].

Factors	Insects	Plants
Temperature	• Evolutionary changes	• Photosynthesis
	• Reproductivity	• Respiration
	• Life period	• Phytochemicals
	• Metabolism	• Germination
	• Activity	• Flowering
	• Migration	
Humidity	• Development	• Transpiration
	• Survival	• Nutrients from the soil
	• Behaviour	• Photosynthesis
	• Physiology	• Pollination
	• Reproduction	• Incidence of diseases
Precipitation	• Survival	• Photosynthesis
	• Development	• Spread of diseases
	• Reproduction	• Development
	• Distribution	• Transpiration
		• Pollination
		• Competitive Suppression
		• Life period
Wind	• Distribution	• Photosynthesis
	• Behaviour	• Transpiration
	• Abundance	• Lodging
	• Reproduction	• Chilling injuries
	• Survival rate	• Pollination
	• Pollinating	
Greenhouse gases	• Reproductive capabilities	• Photosynthesis
	• Distributional ranges	• Stomatal conductance
	• Physiology	• Oxidative stress
	• Behaviour	• Carbon to Nitrogen (C:N) ratio
	• Population dynamics	

The major drivers influencing insect biota through both positive and negative effects are discussed in detail below under distinct subheadings.

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1. Effect of temperature

Climate change is a significant driver of insect pest dynamics, with rising global temperatures, altered weather patterns, and extreme climatic events substantially influencing insect populations. These environmental shifts impact insect survival, reproduction, dispersal, and the number of generations per year (Fig. 1). Consequently, the distribution, abundance, and damage potential of insect pests are undergoing considerable changes [3].

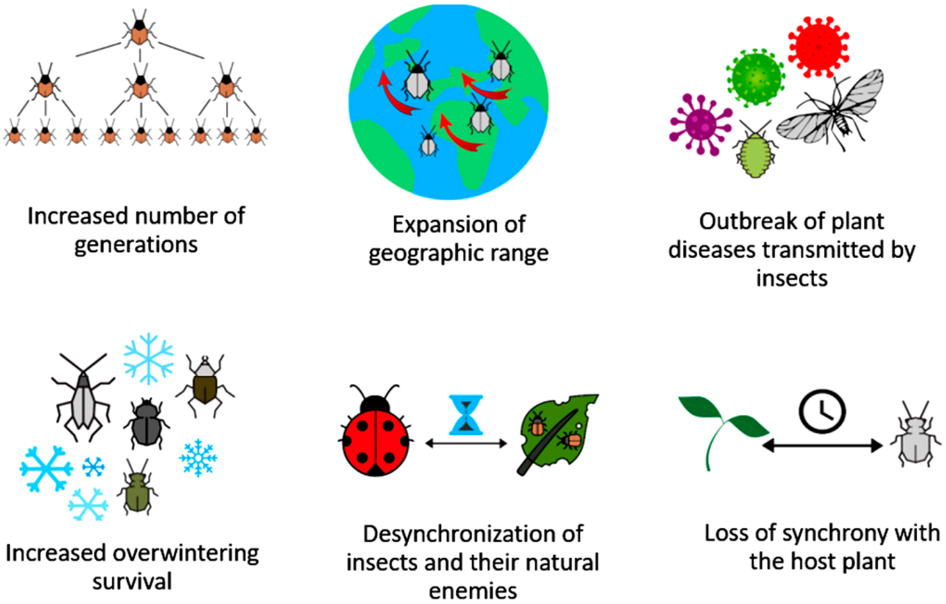

Fig. 1. Effects of temperature rise on agricultural insect pests [14].

Climate change also effects the intricate relationship of insects and plants and have direct impact on their role in ecosystems, agriculture and main kinds. In addition to changing plant physiology and chemistry, it also affects the temperature and precipitation pattern. In tropical ecosystem plant - insects interaction significantly affected by rising temperature helps to increase the atmospheric CO_2 and spell of dry season and the projected increase/ decrease will be pronounced by the end of twenty first century due to increase in temperatures.

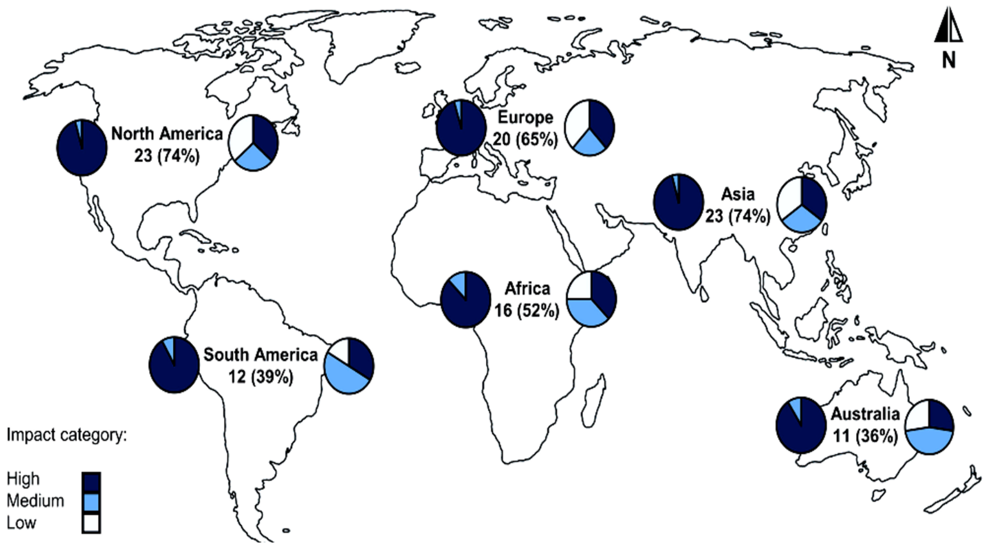

Fig. 2: Factors of climate change and its effect on insects [2].

However, some results indicated that ongoing global warming will negatively impact insects because of thermal suitability and increase in frequency of high temperature extreme that decline population of these insect species. However, based on observations of 31 widely distributed, present in the Northern Hemisphere, [2] suggested a mixed pattern of responses within insect pests to climate warming, although in most cases, pest severity increases (Figure 2).

Change in distribution and abundance of insects are another most significant points that govern by alteration of temperatures as observed in case of whitefly population due to high temperature and humidity. Similarly, a linear relationship was also noticed among severity, frequency and extant of bark and wood-boring insect and temperature increase [15]. Increase in temperature also support rapid development of aphids and the large cabbage white butterfly (*Pieris brassicae* L.), that results more generation per year. Due to increase in temperature migration of aphids was also reported that subsequently lead to outbreak of insects [16].

2. *Effect of carbon dioxide (CO2)*

Rising atmospheric CO_2 concentrations impact the distribution, abundance, and performance of herbivorous insects (Fig. 3). The effect of CO_2 on insect pests is highly dependent on the plants they consume. C_3 crops such as wheat, rice, and cotton are generally more affected by CO_2 levels compared to C_4 crops like maize and sorghum. This difference in plant response to CO_2 can lead to asymmetric effects on herbivory. Insects feeding on C_4 plants may exhibit different responses compared to those feeding on C_3 plants. Increased CO_2 can affect insect consumption rates, growth rates, fecundity, and overall population densities. However, the precise effects are highly specific to individual insect species and their interactions with host plants [17].

Elevated CO_2 can indirectly affect insects by influencing plant physiology. Increased CO_2 levels can stimulate plant growth and productivity through enhanced photosynthesis. This, in turn, affects both the quantity and quality of available plant material for insects. A common consequence of elevated CO_2 is a change in the chemical composition of plant leaves, potentially altering their nutritional value and palatability for leaf-eating insects.

Additionally, CO_2 enrichment can lead to higher sugar and starch content in leaves, which can reduce insect feeding due to an altered carbon-to-nitrogen ratio (C: N). Nitrogen is a crucial element for insect development, and a decrease in the C:N ratio due to CO_2 enrichment can lead to increased plant consumption by some insect groups.

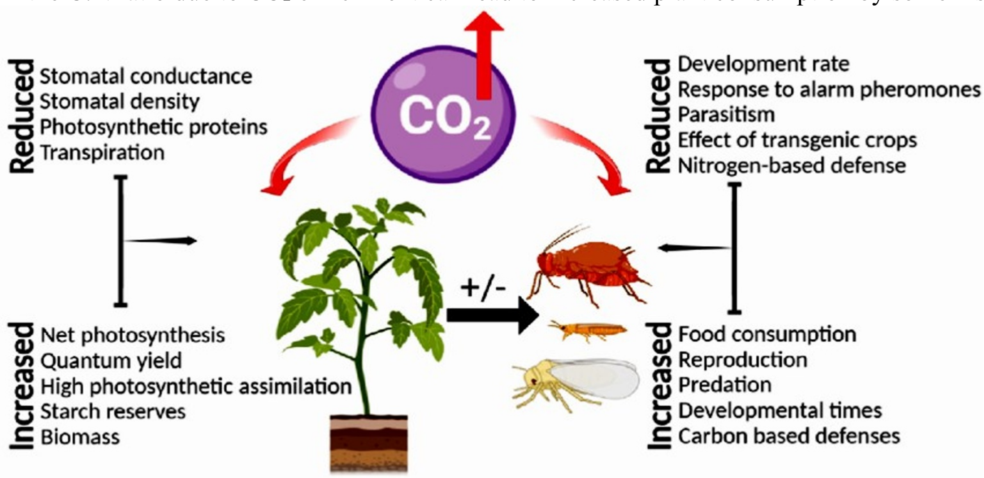

Fig. 3. Impact of atmospheric CO_2 increase on agricultural insect pests.

Host plant resistance is a cornerstone of sustainable pest management, relying on plant-based defences against insect herbivores. It was noticed that at elevated CO_2, plant defence pathways, particularly jasmonic acid (JA) intervene makes plants more susceptible to insects. Hence insects such as Japanese beetle (*Popillia japonica* Newman) and the western corn rootworm (*Diabrotica virgifera* LeConte) are successfully developed because of low production of defensive compounds such as cysteine proteinase inhibitors (CystPIs). Similarly, CO_2 change also disrupt the pheromone mediated insect communication as the studies of speckled poplar aphid (*Chaitophorus stevensis* Sanboen) suggested that increased CO_2 concentration can reduce dispersal behaviour [18].

The response to CO_2 fertilization also varies depending on the insect's feeding behaviour as in case of thrips population increases under elevated CO_2. Phloem-feeding insects like whiteflies and aphids may show a combination of increased population growth rates and decreased population density. In conclusion, rising CO_2 levels present a complex scenario for insect-plant interactions.

3. Changing precipitation

Changes in precipitation patterns are a significant indicator of climate change. These changes often manifest as more frequent droughts and floods, impacting insect populations in many ways. The following examples highlight the complex ways in which altered precipitation patterns can influence insect populations. Some species may benefit from certain aspects of modified rainfall regimes, while others may face significant challenges.
Consequently, understanding these diverse impacts is crucial for predicting and managing insect pest dynamics under a changing climate. For insects that overwinter in the soil, changes in rainfall patterns can be particularly disruptive. Heavy rainfall events can lead to flooding and prolonged water stagnation, threatening insect survival and potentially disrupting their diapause (a period of developmental dormancy). Furthermore, heavy rains and floods can wash away insect eggs and larvae, significantly impacting populations. Small-bodied pests such as aphids, mites, jassids, and whiteflies are particularly vulnerable to being washed away during heavy downpours [14] (Fig. 4).

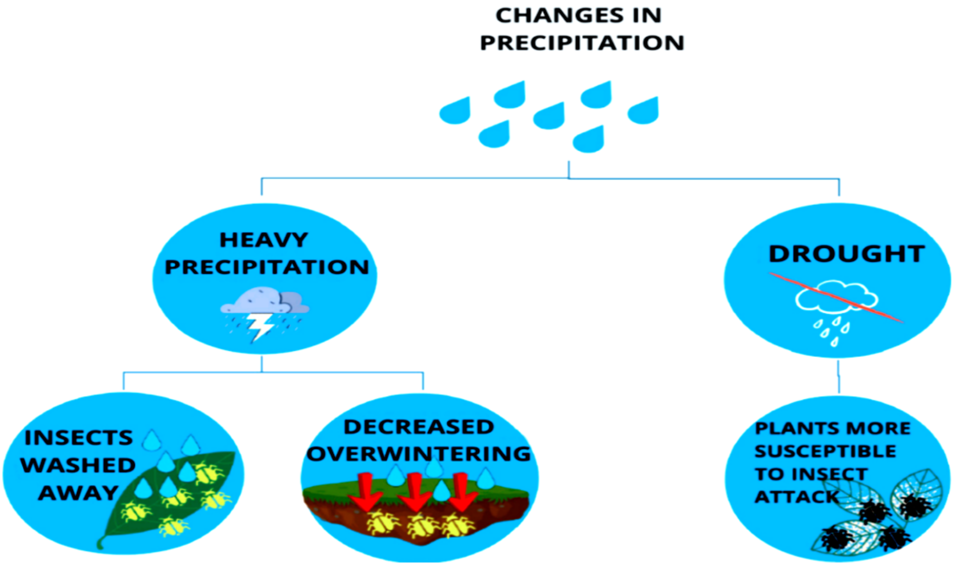

Fig. 4. Impact of heavy precipitation and drought on agricultural insect pests [14].

Rainfall can also directly dislodge insects from their hosts. Raindrops can physically knock off leafhoppers, planthoppers, thrips, and cutworms, while others like mealybugs, pupae of fruit flies, *Helicoverpa*, *Spodoptera*, *Etiella*, and rice stem borers may drown. Interestingly, flooding can be used as a control measure for some pests like termites and stem borers. However, heavy rainfall events can also trigger outbreaks of fungal pathogens that infect insect pests, such as the sugarcane pyrilla.

Finally, it may be deduced that change in precipitation event also modified the quantitative, qualitative and temporal characteristics of precipitation events. It was also noticed that in many insects their survival and reproductions are extremely sensitive to precipitation levels that ultimately affect their populations [14]. Similarly, water stress in plants also disturbed the biological process, which lead to higher susceptibility of plants towards insects and diseases.

4. How climate change affects insect infestation in forest ecosystems

Climate change is generally acknowledged to have a profound impact on forest structure and dynamics [19]. Insect pest organisms respond to these environmental changes both directly and indirectly, through alterations in forest structure and the decreased resistance of trees. Given that insects are physiologically extremely sensitive to temperature, even minor temperature fluctuations can significantly affect forest ecosystems [20].

Urban forests provide a range of social, health, economic, and environmental benefits that substantially improve the live ability of urban areas and human well-being. However, insect pests can severely impact urban trees, leading to defoliation, branch loss, and, in extreme cases, tree mortality, thereby reducing the ecosystem services that these trees provide. It is well-documented that climate change-associated shifts in environmental conditions have a significant effect on plant-insect interactions in natural forests. Nevertheless, in the future, these pest-tree interactions in urban areas may be further altered by the increased variability in environmental conditions projected under climate change. Global warming also affects the forest by altering the mean and variability of temperature and humidity, though for tree growth several internal and external factors are also responsible.

The specific environmental conditions characteristic of urban areas, such as heat island effects and pollution, can induce stress in trees, rendering them more susceptible to insect pest attacks. Furthermore, urban forests are characterized by lower plant diversity and structural complexity compared to surrounding natural forests, which makes them inherently more vulnerable to the impacts of insect pests [21].

Tree-ring width (TRW), a widely used proxy for reconstructing centuries- or millennium-long climate variability globally, generally exhibits a positive correlation with insect outbreaks in various tree species. This pattern has been observed in outbreaks of the eastern spruce budworm (*Choristoneura fumiferana* Clem.), forest tent caterpillar (*Malacosoma disstria* Hübner), larch sawfly (*Pristiphora erichsonii* Httg.), and the larch budmoths (LBMs) (Zeiraphera spp.). For instance, in 1988, LBMs, specifically *Zeiraphera lariciana* Kawabe and *Zeiraphera griseana* (Hübner), caused a significant reduction in the radial growth of Larix principis-rupprechtii Mayr by 47–86% in the Saihanba forest region of Hebei province, North China [22].

Insect pests' distribution

Insecta has many potential representatives that can be used as environmental bioindicators as they have more complex morphology, physiology, more developed sense organs, complex behavior and are characterized by a greater diversity of species, therefore, they can more precise, more rapid and more variable to reflect disturbance of their environment. Now a days policy maker feels that insect are more dependable bioindicators for human driven climatic changes as compared to vertebrates and plants biota [23]. Insect migration is now more frequent in insects particularly in Lepidoptera, Hemiptera and dragonflies. Range shifts are now most frequently recorded in lepidopterans (butterflies and moths) and dragonflies. Such data also appear relatively frequently for true bugs (Hemiptera). It is important to note that climate warming is not always the sole factor driving these shifts; for example, the availability of water bodies can also be responsible for range shifts and invasions.

Abiotic factors' effect on biopesticide sensitivity

Changes in environmental abiotic factors such as temperature, relative humidity, CO_2, and UV radiation have resulted in differential effects on biopesticide efficacy and the activity of entomopathogenic fungi and nematodes. Temperature and humidity are key factors, with extremely elevated temperatures leading to a significant loss of biological activity. For entomopathogenic fungi and viruses, high relative humidity is positively correlated with increased mortality in insect hosts. Conversely, insect viruses are inactivated by extreme temperatures, intense sunlight, and high UV radiation [24].

An increase in CO_2 concentration can significantly reduce spore germination and growth rates of entomopathogenic fungi but may paradoxically increase insect mortality due to disruptions in the carbon-to-nitrogen (C/N) balance within the host and subsequent increases in food consumption by the insect. Similar effects have also been observed on biopesticides based on viruses and bacteria.

The intricate coexistence and interaction of insect's pest and their natural enemies play a crucial role for maintain ecosystem balance. In nature as both – insects pest and their natural enemy's biology and physiology are affected by climatic factors, hence complex tri-trophic relationship between host plants, herbivorous insects and their natural enemies.

Climate change impacts study approaches and their limitations

Currently, various approaches are employed to investigate the effects of increasing temperatures on plant-insect communities. These include field-based warming experiments, glasshouse experiments, species distribution models. While such approaches are particularly useful when considering single species, studying entire communities presents certain limitations, particularly regarding the scope for investigating biotic interactions.

Due to change in abiotic factors such as temperature, moisture, light, air and water currents considerable fluctuation in insects' population occurs in ecosystem, but both herbivorous and non herbivorous keep elements of their present days' structures in terms of communities composition and feeding guild structure.

Due to warm climate insects respond idiosyncratically and because of that for reaching effect was observed in community structure, composition and function of species due to interspecific and intraspecies dynamics of insects due to decoupling of interaction within insects and plants. It was already established that the during last few decades climate change had profound effect on insects via range shift and insect phenology.

Consumer- resource interaction within predators and host insect were also changing insect population within a particular ecosystem due to predation of invasive predators as in case of Wingless fly, (Carabid beetle – *Merizodus soledadinus* Guerin- Meneville) extension on the Kerguelen Islands [25].

In forest ecosystem, due to climate change invasive insects' species such as the hemlock woolly adelgid (*Adelges tsugae*) become a severe threat to large area of eastern hemlock mortality on the eastern cost of USA. Similar ecological and economic losses were observed by invasive pest cotton cushion scale (*Icerya purchasi* , Maskell or Annand and the *Cycad aulacaspis* scale or Asian cycad scale, A*ulacaspis yasumatsui* Takagi) in native fauna of Guam and Galapagos Archipelago.

In different ecosystem mismatch of interaction seen because of change in interaction within species due to change in intra-action due to spatial and temporal decoupling and these structural changes in time and space were clearly visible in tropical as well as temperate regions [26].

Increase in temperatures have clear impacts on insects community structure, affecting their growth rate, physiology, life cycles, geographic ranges, and tritrophic interaction, leading to shifts in species composition, population dynamics, and ecosystem services like pollination [27] and disruption in thèse balance have sévère impact particularly on community composition structure of terrestrial écosystèmes as insects are key player of ecosystem that perform various services (pollination, predation, parasitism) in nature.

Abiotic factors and insect-host plant relationships

As global temperatures rise, precipitation patterns shift, and atmospheric composition changes, the interactions between insects and plants are undergoing significant transformations. Climate change directly influences insect physiology, behaviour, and life history traits. Indirectly, it affects insect populations by altering host plant morphology, biochemistry, and distribution.

Ambient climate also changes the plant chemistry and physiology. Increase in temperatures and CO_2 and changing duration of dry seasons particularly in tropical countries highly influences the plant- insect's interactions. These changes also lead to lower the plants defence against insects as in case of early infestation of *Helicoverpa armigera* Hubner in cotton and pulses in Northern India. Interestingly, high CO_2 concentration also reduces the plant defence system particularly those mediated by Jasmonic acids (JA). However, the Japanese beetle (*Popillia japonica* Newman) and the western corn rootworm (*D. v. virgifera* Leconte) are flourishing because of less production of défensive compound like cystine protéinase inhibitors (CystPIs). It was also reported that insect communication and behaviour are also govern by temperature and CO_2levels.

Additionally, pheromone-mediated insect communication can be disrupted by climate change. It was already established that elevated CO_2 levels can reduced *C. stevensis* dispersal, while increased ozone levels can stimulate dispersal behaviour (18) . Host plant resistance is a cornerstone of sustainable pest management, relying on plant-based defences against insect herbivores. These defences, encompassing antixenosis, antibiosis, and tolerance, are significantly influenced by ambient condition.

It was already proved that the performance of insect herbivores may be strongly affected by drought, CO_2, and by interactions between climate change drivers. Increasing plant C/N ratios and higher leaf tannin content may increase the duration of insect developmental stages because nitrogen acquisition and detoxification of plant secondary compounds are more costly to herbivores.

Climate change, by altering these factors, is disrupting the delicate balance between plants and insect pests. Under stressful environmental conditions, plants become more vulnerable to insect attacks due to weakened defences, leading to increased pest outbreaks and crop losses. However, climate change can interfere with these defence strategies, making plants more susceptible to insect damage. Some plants can induce chemical changes in response to herbivory, deterring further feeding.

Changing climate and insect host adoption strategies

As insects are ectothermic, their physiological response to alterations in their abiotic and biotic environment is crucial for predicting the resilience of natural populations. To cope with climate change in situ, species can track their optimal temperatures by migrating towards higher latitudes and altitudes. However, the capacity and rate of migration towards suitable climate habitats often differ between taxonomic groups, which can create novel plant–insect interactions involving species whose geographical ranges are currently non-overlapping [28].

It has been established that host plant shifts can significantly impact herbivorous insects by altering their reproduction and growth and interactions with a novel host plant may reduce oviposition success, offspring survival,

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and size] [29]. Although generalist herbivorous insects are expected to successfully colonize novel plant communities while specialists might be less likely to do so . Chemical cues play important roles in dictating the discrimination between current and potentially novel host plants, influencing whether larvae can survive and grow successfully.

What influences plant and insect biota and how it is predicted?

In general, it was presumed that the major drivers of phytophagous insect community structure are the physical and chemical characteristics of the host plants, while MacArthur (1972) [30] proposed that community assembly is mainly driven by climatic factors, operating via impacts on species interactions. However, to undertake such studies vegetation model was already developed.

Using degree-day models, studies suggested that the codling moth (*Cydia pomonella* (L.)), peach twig borer (*Anarsia lineatella* Zeller), and oriental fruit moth (*Grapholita molesta* (Busck)) are expected to complete a greater number of generations under future climate scenarios due to the higher rate of heat accumulation. Also, in order to compensate for the decrease in nutritional quality of plant tissues at higher CO_2 concentrations, pests may need to feed more, which can increase cumulative damage to crops. The impacts of warming due to climate change on insect populations could differ when fluctuations in daily temperatures are considered compared to the daily mean temperature, because more frequent climate extremes may negate any beneficial effects of warmer temperatures [31]. Studies were also supported the turnover data of community and structure changes along with latitude and longitudes and field -based warming experiments.

Complexity of prediction studies

How the affect of ongoing global warming remains uncertain because these responses are multifacettes and ecologically complex. Although it is established that insects are sensitive to ambient condition. The prédiction studies on insect dynamics are typically based on observational parameters to spatial and temporal variation in climate/ in controlled condition in laboratory/climate modeling projections or combination of above mention approach and effect of several factors on insects limits the reliability of data as well as analysis. For example such as water and temperature can differ significantly across a species geographical ranges.

In nutshell responses in to four categories namely changes in geographic range, life-history traits, population dynamics and trophic interaction [32]. They further said that any of these can influences the extant of economic damage cause by pests. trophic interactions encompass pest-host shifts, changes in host-plants- pest interaction and pest- enemy interaction. Thus, single factor do not represent the full range of a pests potentiel response to temperature warming.

Knowledge gap in global warming studies

Only after mid1990s attention was given to these subjects with more focus on Lepidoptera and Diptera while Coleoptera (beetle), Hymenoptera (ants, bee, was) and Hemiptera less explored. Interestingly temperature effect (40%) was in top priority of interest followed by unspecific area (27%). Moisture stands third and (14%) and remain studies (4%) covers remaining area of subject. Fundamental biology such as genetics, physiology and behaviour was less covered, hence, to bridge the gap more attention is needed in this aspect. Considering evolutionary change with change in climate more studies are needed toward pest management strategies.

Still at regional and global basis invasive pest was not studied in-depth and critical response across diverse taxa provides a more reliable understanding. Pest response to changing climate is also difficult as insect species exhibit multiple, spatially variable response, thus choosing appropriate management practices is difficult.

Infact, insect response to climate change mainly focused on change in abundance of single species. Thus, data should also needed be addressed for specific type of habitat with reference to heterogenous insect population of specific area to support a comprehensive assessment of insect population dynamics, ecology, physiology, behaviour and genomics. Finally, interpretation become more difficult when in rapid changing climate biology of insect is not well known.

Conclusion

Environmental shifts exert powerful effects on the distribution and abundance of insect species, with climate warming significantly impacting many insect populations and the ecosystems they inhabit. A substantial body of data addresses climatic effects on a range of different insect species and their populations, providing a foundation for describing how insect species are responding to recent climatic trends and offering some generalized predictions for future responses. Indeed, insect species are observed to respond to recent climatic trends, and predictions are being made regarding their future distributions and population dynamics.

Warmer temperatures generally lead to more rapid development and increased survival in insects at mid- to high latitudes, which can account for detectable and unambiguous shifts in a range of insect species over the past half-century. Increased warmth also advances the onset of insect life cycles for the many species that use thermal cues to synchronize life history events with the changing seasons. Owing to their relatively short life cycles, high reproductive capacity, and high degree of mobility, insects' physiological responses to warming temperatures can also generate particularly large and rapid effects on species population dynamics. It is also expected that climatic warming will increase the abundance and distribution ranges of a majority of insect species.

Finaly it is deduced that more data should be generated on various frontier of insects in a densely populated continents of globe particularly in Asia and Africa which experiencing high population density and poor industrial regulation. As in most of the regions basic biology of insects are still scanty and are not reported and across the continent's insect showed variable responses to experiments need more systematic research in this tiny creature which is backbone of ecosystem.

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