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Response of insect and mite pests to climate change: A review

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Abstract
Climate change has a profound impact on agricultural plants and the insect and mite pests associated with them. Understanding abiotic stress responses in crop plants, insect-pests and their natural enemies is an important and challenge ahead in agricultural research. Climate warming has an impact on habitat selection as well as the geographical expansion of insects-pests. Temperature rise directly affects pest's reproduction, survival, spread and population dynamics as well as the relationships between pests, the environment, and natural enemies. As such, it is very important to monitor pest's appearance and abundance as the conditions of their occurrence can change at a high pace. Monitoring and observations of insect activity are fundamental to detecting changes in species composition in a dedicated area as well as shifts in their activity pattern. This review highlights the impact of some of the predicted climate changes, especially the rise of temperature, atmospheric carbon dioxide and changing precipitation patterns as they all contribute to the changing climate that are affecting insect biodiversity, geographical distribution, behavioural preferences and pests' outbreaks that are negatively impacting the agriculture sectors in many countries.

Keywords: Climate change, sustainability, insect-pests, response, agricultural crops, population dynamics

Introduction

Agriculture remains an important pillar of the Indian economy, contributing about 20 percent to the overall GDP (Balkrishna *et al*., 2021) [1]. In recent years, the growing intensity of climatic extremes has posed serious risks to global agricultural production and food security (Pathak, 2023) [2]. Among of all concerns agriculture climate change is one of the most discussed issues in today's society. It has effects on human existence and means of subsistence. The agricultural sector faces numerous challenges; however, climate change has emerged as the most critical issue, becoming one of the most persistent global concerns in recent years (Fusco *et al*., 2020) [3].

The agricultural sector is highly sensitive and particularly vulnerable to the effects of climate change and variations in climatic conditions (Lemi and Hailu, 2019) [4]. Rising temperatures, changes in precipitation patterns, and elevated CO_2 concentrations significantly affect ecosystems at various levels, from individual species to entire ecosystem structures (Stevens *et al*., 2004) [5]. To minimize the adverse effects of climate change on agricultural productivity, numerous management strategies, agricultural practices, and technological approaches are being adopted globally (Okolie *et al*., 2022; Sharma and Chauhan, 2024) [6,7]. Agricultural pests and crop production are heavily impacted by climate change and extreme weather events (Sharma *et al*,. 2017) [8].These effects can include expanding the geographic range of pests, increasing their survival rate during the winter overwintering season, increasing the number of generations, altering the synchrony between plants and pests, increasing the risk of invasion by migratory pests, and reducing the effectiveness of biological control, especially natural enemies. This poses a serious threat to crop economics and human food security (Mahanta *et al*., 2023) [9].

One of the major biotic factors are pests, which are also impacted by climate change and weather disruptions. Insects are essential for a variety of ecosystem services. They are superb pollinators for many of the economically significant crops (Kumari *et al*., 2024; Sharma *et al*. 2024; Bhatia *et al*., 2024) [10,11,12]. When insects interact with various competitors, predators, and parasitoids and impose costs at various life stages, their responses to a quickly changing climate may also vary. This may also have an impact on larger food production systems, which may be seriously at danger from the effects of climate change (IPCC, 2014) [13]. The responses of pests to climate change are complex as they are indirectly impacted by the responses of their host plants, competitors, and natural enemies. Furthermore, the variability of the atmosphere and uncertainty of measurements in an open system increase the complexity of assessing the responses of insect and mite pests to climate change. Increased temperatures, CO_2 and rapid changes in rainfall patterns can dramatically alter the biochemistry of plants and thus plant defence responses (Sharma *et al*., 2026) [14]. Along with the negative effects of climate change, rising temperatures and carbon dioxide (CO_2) levels may increase photosynthetic rates in regions with medium to high latitudes, enhancing agricultural output (Asseng *et al.*, 2015) [15].

Variations in vegetation characteristics affect higher order interactions of predation and parasitism, plant competitiveness, the frequency of insect and mite pests that are linked with them. As a result, the effects of climate change will be felt throughout the entire food chain (Hoekman, 2010) [16]. Extreme weather conditions such as high temperature, an increasing level of carbon dioxide gas (CO_2) in the atmosphere and heavy precipitation all contribute to the shift in the global climate that are affecting the biodiversity of insects, their geographical distribution, their behavioural preferences and the rapid pests' outbreaks due to ineffective pest management interventions that some countries are challenged with and the agriculture sectors are being faced with on an annual. Natural enemies are also equally affected by these environmental changes (Bhagarathi and Maharaja 2023; Meenu *et al*., 2025) [17,18].

A potentially workable alternative to IPM is provided by host-plant resistance, bio pesticides, common enemies, and agronomic techniques (Istatu *et al*., 2025) [19].This review will investigate the consequences of some of the predicted climate changes, particularly the rise in atmospheric CO2 concentrations and temperatures, as well as the effects of changing precipitation patterns, on the biology and ecology of harmful insects-pests.

Climate change–induced changes in crop production

Global climate changes have significant impacts on agriculture and also on agricultural insect pests. Climate change represents a multifaceted and persistent challenge to agricultural sustainability, particularly in a country like India, where a large proportion of the population depends on farming for their livelihood. Agricultural crops and their corresponding pests are directly and indirectly affected by climate change (Nayak *et al*., 2023) [20]. For this review, it is important to first explain the effects of climate change on crop production, as the effects of climate change on insect and mite pests depend on the plant species on which these insects thrive and feed. The principal climatic determinants include temperature, precipitation, and atmospheric greenhouse gas concentrations. These variables significantly influence plant metabolic processes, physiological functions, pest population dynamics, soil nutrient status, and the availability of irrigation water (Malhi *et al*., 2021) [21]. Significant uncertainty remains concerning the extent to which elevated atmospheric CO_2–mediated physiological modifications in plants interact with climate change–associated environmental variability to regulate crop productivity (Gornall *et al*., 2010) [22]. Variations in temperature, precipitation patterns, and elevated atmospheric CO_2 levels have complex and often interconnected effects on crop productivity. While increased CO_2 may enhance photosynthesis and water use efficiency through processes like Photosynthesis, the accompanying rise in temperature and erratic rainfall patterns can offset these benefits by inducing water stress, reducing nutrient efficiency, and disrupting crop developmental stages. Moreover, the increased frequency of extreme climatic events such as droughts and floods further intensifies the vulnerability of agricultural systems, threatening food security and economic stability.

Impact of temperature increase on crop production

Crop species possess defined temperature requirements for the progression of distinct phenophases and the completion of their life cycle. Exposure to temperature extremes, both low and high, can significantly impair developmental processes and yield formation, especially during critical stages like anthesis (Luo, 2011)[23]. Additional increases in temperature are likely to affect crop productivity more quickly in areas where crops are already growing near their physiological temperature thresholds (Singh and Sharma, 2017)[24].Vegetable crops characterized by high transpiration rates are particularly vulnerable to elevated temperature conditions, as excessive heat intensifies transpiration, thereby imposing physiological water stress that restricts plant growth and productivity. It is reported that rising spring–summer air temperatures are anticipated to positively influence crop production in northern regions by extending the growing season, which is presently a major limiting factor. Increased night time temperatures associated with global warming lead to a significant reduction in rice yields (Tubiello *et al*., 2002) [25].

Impact of elevated CO_2 on crop production

The primary effect of the response of plants to rising atmospheric CO_2 is to increase resource use efficiency. Higher atmospheric CO_2 concentrations enhance carbon uptake and assimilation, thereby accelerating plant growth and development (Holly, 2022) [26]. *Poorter et al., (1997)* [27]conducted experiments on 27 C_3 plant species under ambient and elevated CO_2 conditions and found that increased CO_2 led to higher accumulation of non-structural carbohydrates and reduced nitrogen content in leaves. Elevated CO_2 conditions enhance photosynthetic activity, leading to increased leaf expansion, biomass accumulation, and overall crop yield. Additionally, CO_2 enrichment reduces transpiration rates per unit leaf area.

Impact of changeable precipitation pattern on crop production

Projected climatic shifts, coupled with an increasing frequency and intensity of hydro-meteorological extremes, are expected to significantly affect dry land ecosystems, leading to alterations in agricultural resource demand as well as modifications in production systems and processes (Chatterjee, 2018) [28].

Impact of climate change on insect and mite pests

Many insects and mite pests have huge populations and rapid generation rates, and they may adapt quickly to climatic change in terms of phenology, fecundity, survival, selection, and habitat utilization. Insect abundance and distribution may alter quickly as a result of these changes to their life histories. Direct impacts are on pests' reproduction, development, survival and dispersal, whereas indirectly the climate change affects the relationships between pests, their environment and other insect species such as natural enemies, competitors, vectors and mutualists (Prakash *et al*., 2014) [29]. Nearby species including social insect nests, insect herbivores are affected by changes in leaf surface temperature and humidity through stomata opening, and leaf miners positioned under the leaf lamina all have an impact on the organisms.

According to Eigenbrode *et al*., (2015) [30] pests may directly respond to climate change in a variety of ways. Different structures, such as rocks, dirt, the terrain, and the plant canopy, have an impact on abiotic settings. Local organisms, including common herbivore insects, have an impact on biotic habitats. Insects and mite pests are primarily influenced by changes in the temperature and humidity of leaf surfaces caused by stomata opening. European red mite *Panonychus ulmi* (Koch), a major pest of apple in Himachal Pradesh usually peaked in July-August (18-21ºC and 82-90%) with the mean population of 83.08 active stages and 162.12 eggs/leaf; showed positive correlation with ambient temperature and humidity while, negative with rainfall (R^2-64.96% for active stages; 48.88% for eggs)(Sharma and Bhardwaj 2004; Sharma and Thakur, 2004; Sharma 2023) [31, 32, 33]. It is challenging to forecast climate change since organisms can modify both abiotic and biotic surroundings to some extent in search of their most favoured climate (Gia and Andrew 2015) [34].

1. Response of insect pests to increased temperature

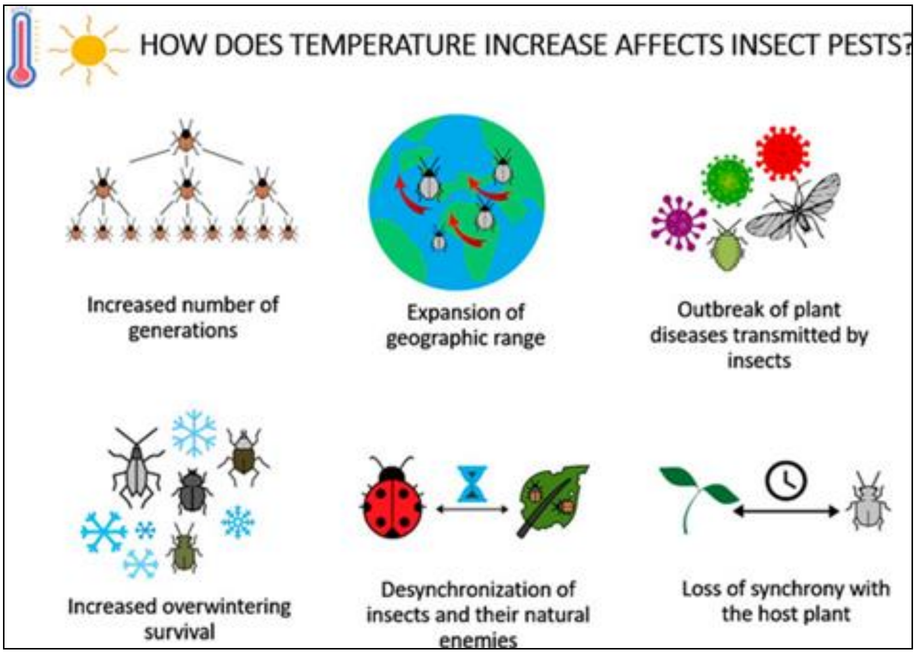

Fig 1: Effects of temperature rise on agricultural insect pests.

Plant protection strategies have greatly benefited from the incorporation of thermal biology into the study of insect pest population dynamics, fluctuations, and demographics. Under a hotter and more erratic environment, this research field will continue to offer insights for predicting pest outbreaks in the next decades (Bale and Hayward, 2010; Colinet *et al.*, 2015) [35, 36].Days with high temperatures are prevailing more frequently in agricultural crop areas. Different developmental stages are being exposed to extremely hot temperature events that may affect insect pest ontogeny, preventing maturity and altering adult reproduction, feeding, and growth rates. Several effects of temperature on insects were listed by Tanveer *et al.*, (2025) [37] including changes in geographic range, overwintering, population growth rates, number of generations annually, crop pest synchronization, dispersal and migration, and accessibility to host plants and refugia.

Pest insects will proliferate more as a result of rising temperatures, and temperature changes will have an impact on practically all insects. This entails the intensification of yield losses due to potential changes in crop diversity and increased incidence of insect-pests (Sharma, 2025) [38].Insect life cycles will get shorter as global temperatures rise by one degree. The population of pests will increase as the life cycle shortens. Because most insects in temperate regions grow during the warmer months of the year, species whose niche space is defined by climatic regime will respond to climate change more predictably than those whose niche is restricted by other abiotic or biotic factors (Asseng *et al.*, 2015)[15].The temperature has a significant direct influence on the population dynamics of insect pests through their life histories and morphological characteristics, as well as an indirect effect through its impact on perennial plants and natural predators (Johnson and Haynes, 2023) [39].

Interactions between species will shift as a result of insects changing their behaviour in search of the best thermal settings. The interactions between the parasitoid, *Aphidius rhopalosiphi* (Aphidiidae: Hymenoptera), the main natural adversary of the cereal crop aphid *Sitobion avenae* (Aphididae: Hemiptera), and the two species were altered when the temperature varied by 5°C (Le Lann *et al.*, 2014) [40].The maximum rate of Oviposition was seen in parasitoids at the "resting" temperature of 20°C. Aphid metabolic rates and defense against parasitoid attacks increased more when temperatures were raised to 25°C than did those of the parasitoid. As a result, the effectiveness of parasitoid control of aphids may decline. Attacks on mobile species increased along a temperature gradient (from 5°C to 30°C) whereas, attacks on resident prey species remained constant along the gradient in a predator-prey system that included predatory ground beetles (Carabidae), mobile adult prey (*Drosophila*, Drosophilidae: Diptera), and resident prey (a larval Alphitobius, Tenebrionidae: Coleoptera).

Insects possess limited thermoregulatory capacity, they rely on a diverse array of physiological, behavioural, and ecological adaptations to persist under thermally stressful conditions. For taxa regularly subjected to cold stress, it is hypothesized that projected warming of approximately 1–5°C over the next 50–100 years may enhance overwinter survival across certain climatic regions (Bale and Hayward, 2010)[35]. Ma *et al.* (2021) [41] demonstrated that exposure to extreme high-temperature regimes significantly reduced development, reproduction, and overall fitness of *Rhopalosiphum padi* compared to predictions based on mean temperature. The negative impacts were more pronounced under regimes simulating higher mid-latitude conditions, highlighting the critical role of thermal extremes in shaping organismal vulnerability under climate warming.

2. Changes in insect-Pests diversity

A better understanding of the disappearance of genes, species, and ecosystems has resulted from a greater awareness of the degeneration of biological systems during the past few decades. Because insects are excellent indicators of environmental change and are crucial components of food chains, the diversity of insects in a habitat reveals the state of an ecosystem. India is home to 6.83% of all insect species worldwide (Baker *et al.*, 2015)

[42]. The relative abundance of various insect species may fluctuate due to climate change, and any species that cannot adapt to the changes may eventually become extinct (Thomas *et al*., 2004) [43].

Many rare, unique, and exotic species of vibrant butterflies only exist in the Western Ghats of India. Due to the destruction of natural vegetation for various anthropogenic development activities, several butterfly species are actually in danger nowadays (Gia and Andrew 2015) [34]. In order to strengthen system resilience and lessen the severity of losses brought on by insect pests, functional diversity needs to be increased in agro-ecosystems that are vulnerable to climate change (Newton *et al*., 2009) [44]. Nearly 45 to 275 species are going extinct every day as a result of climate change, which has caused extinction rates to be 100 to 1,000 times higher than they were previously (Nasim *et al*., 2018) [45].

3. Expansion of geographical ranges

The geographical distribution and quantity of plants and animals in the natural world are influenced by the unique climate needs that each species has for development, survival, and reproduction. With a rise in temperature, places that are currently unfavorable due to low temperatures can start to improve. The global distribution of insect species is largely determined by minimum temperature rather than maximum temperature; as a result, any increase in temperature will increase an insect's capacity to overwinter at higher altitudes, ultimately leading to a shift in the pest intensity from the south to the north**.** The geographic ranges of many bug species are constrained by temperature rather than vegetation as a direct limiting factor. Previous studies have showed that insect pests are likely to shift the places where their host plants are grown from the tropics and subtropics to temperate regions at higher altitudes as a result of rising temperatures (Nasim *et al*., 2018) [45]. Global climate change is expected to result in the range extension of migratory species like *H. armigera* (Hubner), a significant pest of cotton, pulses, and vegetables in North India.

4. Changes in insect phenology

The biology and phenology of insect pests are significantly impacted by climate change and weather changes. Insect pests react differentially to various climate change conditions as typically adaptive creatures. Insect population dynamics, nocturnal activity, growth rate, reproduction, winter performance, and diapause are all complexly impacted by these changes. Through altering host plants and rivals, they also have an indirect impact on insects. Because tropical regions have historically experienced less climatic variability and because tropical insects are already more prone to harmful thermal maxima than temperate insects, research suggests that tropical insects are more vulnerable to warming conditions. Different species react differently to climatic fluctuation even within the same landscape, notwithstanding the difficulty of predicting the precise impact of climate change on insect biology and phenology. (Akram *et al*., 2019; Skendižić *et al*., 2021; Chandrakumara *et al*., 2023; Hassan *et al*., 2023) [46,47,48,49]. In their 2005 study on the effects of climate change on four species of Mediterranean insects—butterflies, bees, flies, and beetles—Gordo and Sanz (2005)[50] found that all four species had altered the timing of their initial appearance over the previous 50 years, and this change was associated with rising spring temperatures. Similarly, light, suction, or pheromone traps can be used to record the timing of bug species' arrival. The timing of pest manifestation might shift as a result of climate change, according to an analysis of long-term phenology data. Analysis of suction trap data has revealed that spring flights of the potato aphid (*Myzus persicae* (Sulzer) started two weeks earlier for every 1ºC rise in combined mean temperature of January and February.

5. Increased Overwintering Survival

Diapause is a time when developmental processes are halted, and how it manifests depends on the environment, including the temperature, humidity, and photoperiod. Diapause is an adaptive characteristic that plays a crucial part in the seasonal regulation of insect life cycles, giving the insects a greater chance to survive numerous environmental hardships. Aestivation and hibernation are the two main kinds of insect diapause that let insects survive in high- and low-temperature environments, respectively According to studies, global warming is more pronounced at high latitudes and happens more noticeably in the winter than in the summer.

6. Increase in number of generations

Depending on the temperature, certain crop pests develop slowly and then quickly. During periods of time with optimal temperatures, they grow more quickly. As these species of insects develop more quickly due to higher temperatures, there may be more generations per year According to estimates, insects may go through one to five more life cycles per season with a 2ºC temperature increase. Studied were conducted to determine the effect of various weather factors on the population of European red mite, *Panonychus ulmi* (Koch) on apple in Himachal Pradesh. The population of *P. ulmi* increased with the rise in temperature corresponding with more number of generations in a season (Bhardwaj and Sharma, 2009, 2012) [51, 52].Warming could reduce the frequency of extreme cold occurrences, which could increase the area where insect pests can overwinter. Thus, if global temperatures rise within a favourable range, tropical and subtropical insects may develop, reproduce, and survive at faster rates. Insects will be able to produce more generations every year as a result (Petzoldt and Seaman, 2010) [53].

7. Introduction of invasive alien species

For an alien insect to become invasive, it must first successfully reach a new habitat, adapt to the conditions, and thrive. Climate change can either facilitate or hinder this process, depending on how it influences the conditions necessary for the survival and spread of these species. The climate, in combination with landscape features, determines the boundaries for species dispersal and influences the seasonal conditions essential for their development, growth, and survival in a new environment (Eickermann, *et al*., 2023) [54]. Climate change may encourage the introduction and spread of exotic species. With the change in the temperature, there is an increased risk of introducing invasive alien species. Although there are many other factors that contribute to biological invasions, climate change and biological control are recognized as the main culprit despite the fact that other factors also have a role. The odds of exotic introductions have significantly and plausibly grown as a result of the globalization and deregulation of agricultural trade on a global scale, as well as the modern, quick access to transportation and communication. Invasive alien species, which change the regional structure diversity of agriculture, forestry, and aquatic ecosystems, are the biggest threat to biodiversity loss in the world.

Pest population dynamics and outbreak

Insect species can develop and reproduce more quickly when the average temperature rises, which leads to shorter life cycles, more larvae on a single host plant, and more outbreaks on a regular basis which can have an impact on population size, genetic composition, and the amount of damage they cause to host plants. According to the population model of the grape berry moth *Paralobesia viteana* Clemens from the family Tortricidae, a temperature increases of more than 2°C may have a significant effect on its voltinism and cause a change in the timing of its ovipositional period, which is currently regulated by photoperiod-induced diapause (Sharma, 1998; Sharma and Bhardwaj, 2005 & 2009) [55,56,57]. With fewer cohorts in low-temperature regions and more in warmer ones, *Spodoptera eridania* Stoll (Southern armyworm) belonging to the family Noctuidae exhibited voltinism and has been reported to range from 2.9 to 9.2 generations in Brazil's current climate, and under climate change scenarios, this number was projected to rise significantly. In one study from India, the annual *H. armigera* Hubner (cotton bollworm) generation increased to 12.9, 13.3, 13.8 and 14.2 respectively, with mean temperatures anticipated to rise by 0.51°C, 1.03°C, 1.57 °C and 2.1°C in climate years 2030, 2050, 2070 and 2090. Future climate years in India will see a 3-12% increase in *H. armigera* generations.

1. Crop pest interaction

Global warming increased temperatures may accelerate the life cycles in some of the plant species (Willis *et al.*, 2008)[58]which may affect significantly, feeding and reproduction patterns in associated insect pests like aphids, jassids, mealybugs, and mites etc. Such increases can greatly exacerbate the negative ecological and economic consequences. An insect that feeds on plants must be able to adapt to its environment as well as its host plant in order to finish developing.

2. Increased prevalence of plant diseases spread by insects

Insects act as important vectors that transmit many plant related diseases such as viruses, phytoplasmas and bacteria. Climate change globally favours the occurrence of insect-transmitted plant diseases due to geographic expansion and increases in populations of insect vectors. The main order of insects that transmit plant viruses are the sap feeding-Hemiptera and include the families of aphids (Aphididae), leafhoppers (Cicadellidae) and whiteflies (Aleyrodidae) as the major vectors of viral diseases (Bhat *et al.*, 2022) [59]. Among the above mentioned, aphids constitute the largest group of vectors, transmitting more than 275 virus species. Rising global temperatures, especially the increasing occurrence of extreme heat events, represent a significant risk to the survival and biodiversity of insect populations (Li and Wang, 2025) [60].

Response of insect pests to elevated CO_2

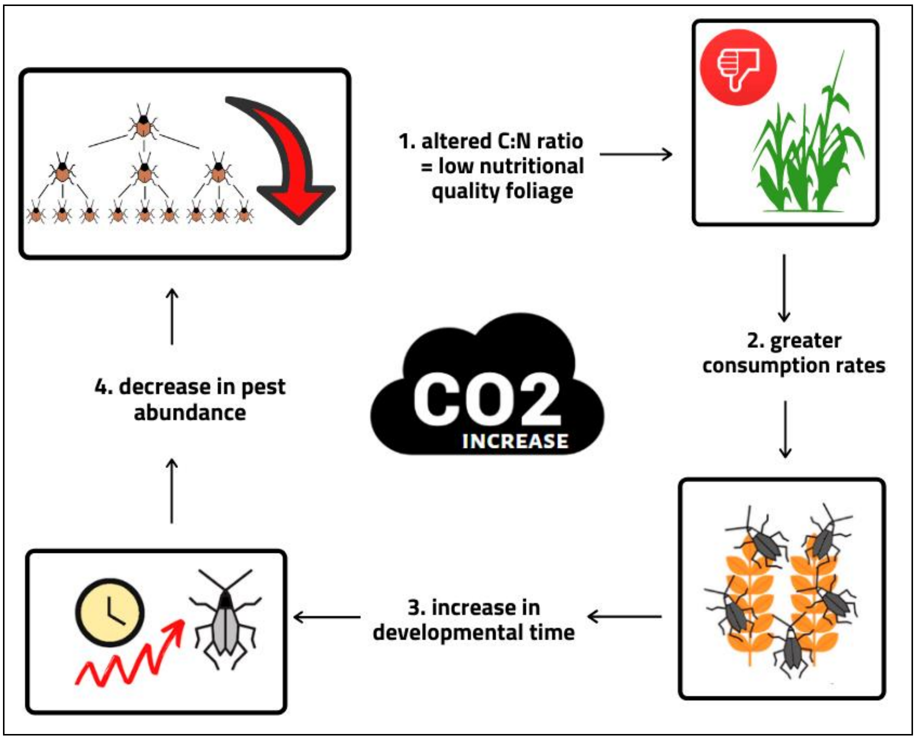

Fig 2: Impact of atmospheric CO_2 increase on agricultural insect pests

Scientists initially believed that raising CO_2 would be a solution for the world's food supply because CO_2 boosts the photosynthetic rates of the majority of crop plants. The insects consume more when plants are grown in high CO_2 environments to make up for their poor nutritional content. Due to the build-up of non-structural carbohydrates in plant tissues, an increase in CO_2 in the atmosphere typically results in an increase in the carbon to nitrogen ratio, which lowers the nutritional quality for insects with low protein requirements by diluting the nitrogen content by 15–25% in the tissues. The research by Sharma (2002) [61] on European red mite, *P. ulmi* in apple revealed that when the nitrogen content of the apple trees is increased by 25% the performance of mite is influenced largely with shorter life cycle and increased multiplication rate.

A quantitative analysis of plant–insect interactions conducted under elevated CO_2 found that changes in host-plant quality—particularly reduced nitrogen and increased carbohydrates—significantly influenced herbivore performance. Their results indicated that insect responses were feeding guild-specific, with leaf-chewers compensating through increased consumption, while other groups showed reduced growth and fitness. Elevated CO_2 environments were found to promote reproductive output in the grain aphid, *Sitobion avenae*, leading to an earlier onset of reproduction and higher daily nymph production, thereby indicating a likely intensification of pest pressure under future atmospheric conditions.

3. Response of pests on change in precipitation pattern

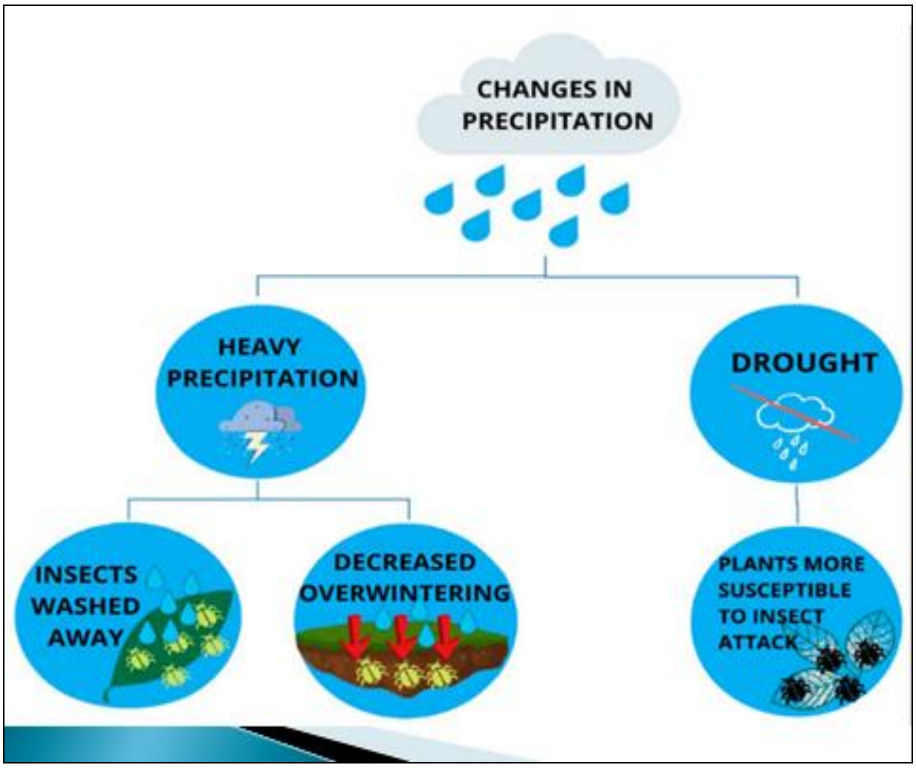

Fig 3: Impact of heavy precipitation and drought on agricultural insect pests.

Both the distribution and regularity of rainfall may directly and indirectly influence the prevalence of pests. Different species of root herbivore reacted differently to changes in summer rainfall. Climate projections suggest a shift toward less frequent but more intense rainfall events, resulting in alternating periods of flooding and drought. Such conditions may reduce the occurrence of small-bodied pests like aphids, jassids, whiteflies, and mites, as heavy rains can physically dislodge and remove them from crop surfaces (Pathak *et al*., 2012) [2]. Higher November rainfall favoured a higher infestation, according to research on rainfall variations throughout the monsoon and November and their relationship to the degree of *H. armigera* (Hub.) damage. Higher July-August rainfall declined the infestation of Two-spotted spider mite, *Tetranychus urticae* Koch in strawberry according to research on rainfall variations throughout the monsoon and resulted in the outbreak of mite attack in dry months of April-May and October-November (Sharma, 2022) [62].

In many cases, rainfall events have become less frequent but more intense, a shift that increases the likelihood of both drought conditions and flooding episodes (Skendžić *et al*. 2021) [47]. Winter precipitation was found to increase the mortality of overwintering pupae of the pest *H. armigera*, although its overall influence remained relatively low (Huang and Li, 2015) [63]. The population of molluscs is high during rainy season causing serious problems in cultivated and non-cultivated areas in high hill regions (Sharma *et al*., 2025) [64].Correlation between European red mite, *P. ulmi* and precipitation found that peak in mite population on apple was recorded when humidity exceeded above 70% (Sharma and Bhardwaj, 2004; Bhardwaj *et al*., 2006; Bhardwaj and Sharma, 2008) [65, 66, 67]. Sprinkler simulations of varied rainfall intensities can be used to study the impact of rainfall on pests. Rainfall and sprinkler watering had a negative impact on the aphid population on wheat and other crops.

Conclusion

Distribution and abundance of insect pests has expanded under the changing environmental parameters. Many species have built resistance and have been able to adapt in the new environment. Increase in agricultural pest is causing incidence of pest outbreaks, pest resurgence, increased adaptability of insects barring the required quality and quantity production of food crops. Additionally, climate change significantly alters the dynamics of insect pest populations, thereby compounding the challenges faced by agriculture. Changes in temperature and CO_2 levels influence pest survival, reproduction, and feeding behaviour, often leading to increased pest pressure and crop damage. Therefore, there is an urgent need to adopt integrated and climate-resilient agricultural strategies, including improved crop varieties, sustainable farming practices, and effective pest management approaches. Such measures are essential to mitigate the adverse impacts of climate change and ensure long-term agricultural productivity and environmental sustainability. These abiotic factors also influence plant growth, development, and reproduction. These interacting factors are complex, and further studies are needed to obtain relevant data to understand the relationships between these factors and pests occurrence. Thus, there is a need for long-term research on the effects of climate change on insect pests both in controlled and field experiments, to collect sufficient data to enable develop accurate predictive models for this relationship. Plus, the decision makers and stakeholders should involve in developing the model so that it is more relevant and reliable to the real field. A climate-intelligent approach is a way forward to ensure that our food security is not compromised in the future by pest infestations on our crops. Sustainable management of pests will play a significant role in this approach.

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