Effect Of Climate Change On Plants And Their Pollinators- A Review

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Abstract
Changes in temperature, disturbances on rainfall pattern, time of growth, flowering and maturation of plants, or any other environmental variation over the entire season can have serious impact on plants associated biodiversity, which in turn may alter the abundance, diversity and foraging behavior of pollinators. For any successful pollination interactions, there is a need of occurrence of synchronous biological events such as insect emergence, their foraging behavior and date of onset of flowering. In this paper, efforts have been made to review the effects of climate change on the phenology of plants and activities of insect pollinators by compiling the available information from research papers, articles, reports and literature in chronological order.

Keywords: *Adaptation, Biodiversity Conservation, Ecotype, Honey bee, Genetic diversity*

I. INTRODUCTION

Reproduction process is the critical stage of most of the flowering plants in which pollinating animals plays an important role for transferring genes within and among populations of wild plant species [1]. Reports by [2], [3] confirms that pollination improves the yield and quality of plants, such as fruits, vegetable seeds, spices, oilseeds and forage crops. It is the most important mutualistic interaction between plants and insects and ecosystem services for sustainable production. [4] States that the insect pollinators provide an important ecosystem function to global crop production through their pollination services. Indeed, several authors [5], [6] have argued that inclusion of species interactions during analysis of the ecological effects of climate change is of utmost importance. Use of pesticides [7, 1], Invasive species [8, 9], habitat fragmentation [10, 11], [12] agricultural intensification [13, 14] along with the multiple environmental pressures [15] negatively affects the plant-pollinator interactions.

In a recent review, [16] reported that the timing of occurrence of flowering and activity of pollinators seems to be strongly affected by temperature. There may be variable reaction of insects and plants in response to changed temperatures, creating temporal (phenological) and spatial (distributional) mismatches resulting in severe demographic consequences for the species involved. These mismatches severely affect the plants by decreasing the insect visitation and pollen deposition, while pollinators experience reduced food availability.

Monocultures practices usually limit the availability of floral resources in a specific time period. Pollinator and pollen limitation both reduce the seed and fruit production in plants. Therefore, reduction in the crop pollination service in the season with the loss of pollinators early in the season may be seen. Thus, the climate change may be a further threat to pollination services [15], [16], [17] and can have very serious impact on insect pollinators and flowering plants. Though the effect of climate is a major issue now-a-days which is negatively harming the insect pollinators. But still the sknowledge of the effects of climate change on mutualistic interactions of plant pollinators is limited [18], [19]. Hence, an attempt has made to review the effects of climate change on insect pollinators by reviewing secondary source of information like review of journal papers, proceedings papers, internet sources, concerning books, study / research paper etc. and to suggest future respective.

A. Scenario of climate change in 21st century

Estimates from the IPCC indicated during the 21st century that average global surface temperatures will further increase between 1.1˚C (low emission scenario) and 6.4°C (high emission scenario) and that increases in temperature will be greatest at higher latitudes. Current climate change models predict that by 2100 there will be an overall warming of world climate between 0.6°C (greenhouse gas concentration maintained at 2007 levels) and 4°C (intensive use of fossil fuels with rapid world economic development) [20]. Further, Hegland [16] and Deutsch [21] reported that distribution of species is expected to shift towards poles and higher altitudes as increased temperature exceeds the thermal tolerant levels of the species.

The impacts of climate change depend upon the physiological sensitivity of organisms to change on different environmental factors. Scientific evidences shows that changes in the distribution and phenology of many plants and animals are predicted from global warming in the last few decades [22], indicating change in global events by 2.3 days per decade and a species range shift of 6.1 km per decade towards the pole [23].

Deutsch [21] found that an expected future temperature increase in the tropics (although relatively small in magnitude) will have more deleterious consequences than changes at higher latitudes. The reason for this is that tropical insects are relatively sensitive to temperature changes (with a narrow span of suitable temperature) and they are currently living in an environment very close to their optimal temperature. Whereas the insect species at higher latitudes have broader thermal tolerance and are living in cooler climates than their physiological optima. Warming may actually enhance the performance of insects living at these latitudes. It is therefore likely that greater population decrease and extinction of native pollinators will be seen in tropical agroecosystems than agro-ecosystems at higher latitudes [21].

B. Effect of climate change on phenology of plants

The timing of pollination is determined by climatic indicators such as temperature and water availability [24]. Plant species flowering early in the season appear to be most sensitive [25], [26] indicating their thermal-sensitive phenologies. There is clear evidence of prolonged growing seasons in many plant communities in Europe during the last decades [27]. In general, the onset of flowering appears to be correlated with the mean temperature in the month of flowering or the months prior to flowering [28], [29]. Also, other potential cues for flowering initiation include photoperiodicity, precipitation, soil humidity and snow melt [30], [31] as well as a particular combination of cues [32].

For any successful pollination interactions, there is a need of occurrence of synchronous biological events such as insect emergence, their foraging behavior and onset of flowering period. Changing climates may cause changes in the time of growth, flowering and maturation of crops, with consequent impacts on plant-associated biodiversity, particularly on pollinators [2]. Thus, affecting the phenology and distribution ranges of both crop plants and their most important pollinators, leading to various mismatches. It is therefore important to identify the temperature sensitivity of the most important pollinators and their plants, and the environmental cues controlling the phenology and distribution of the identified species.

Climate change effects on seasonal activity in terrestrial ecosystems are significant and well documented, especially in the middle and higher latitudes [33]. Climatic condition determines the reproductive behavior of any individual species. The appearance of the buds, leaves, bloom, pollination, fertilization and seed dispersal are all correlated with the weather patterns [34]. Recent global changes in climate such as increasing temperature have notable effects on the timing of phenology of plants. There is a shift in flowering time and the magnitude of phenological responses between different species due to changes in temperature [35],[36], [37]. Galloway and Burgess [38], [39] reported that changes in flowering date of plants may affect reproductive traits of offspring by reducing seed setting, seed size, composition, dormancy and the time of seed dispersal.The effects are however variable across space and between species [40]. Global climate change may force variation in timing, duration and synchronization of phenological events in tropical forests [41]. Trends of erratic precipitation and increasing temperature are likely to reduce the length of the growing season by affecting the timing of leaf-flush and leaf-fall and increasing the leafless period, though to varying extents in different functional types [42].

Several studies have shown significant variation (advanced or delayed) in onset dates of flowering [26] and fruiting responses in tree species as a result of climatic change which may lead to serious implications on future reproductive success of the plants [43]. Several studies have considered the possibility that global change may lead to changes in critical day length for plants [44], [45] or changes in geographic distribution [19].

Changes in phenological behavior of plants may have consequential effects on production (in agriculture, horticulture, viticulture, and forestry), human health (e.g. through earlier pollen release and insect infestations), distribution of species, their community composition, and their life cycles following warming up of the climate. A changed phenology not only just affect wildlife, moreover it may have serious economic and social implications [33], [46]. Studies in the past have indicated that the climate change has produced noticeable effect on phenophases in plants.

This shift in the phenophases over the years is one of the reasons for substantial reduction in fruit yield as observed in case of apple plantation [47]. Climate change will force deviations in the length of the growing period and competition among species may alter the resource use patterns in different species [43]. Extended phenology would tend to increase resource acquisition, where as compressed phenology decreases resource acquisition. This can be explained by the fact that elevated temperature shortens the grain-filling duration thus reducing the grain yield [48], [49]. The competition among species is likely to get modified, if their phenological behavior is differently sensitive to environmental conditions. Due to changed competitive relationships, the species composition of forests and possibly geographic range of species will change in the long run [42], [50]. The phenological change in flowering events may break the equilibrium rhythm of plant–insect interactions, thus causing shifts in the dynamics of pollinating insects and associated tropic communities [51]. All shifts in phenological phases, especially in the leaf period, have impacts on the climate system itself via feedback mechanisms of surface albedo, carbon-dioxide fluxes and evapo-transpiration [52]. Differences in phenological responses to climate change are generally not isolated to individual organisms [53] but may cause uncertain ecological consequences, with implications for ecosystem stability and function [54], [55].

C. Effect of climate change on activity of pollinators

Insects are considered to be among the most important pollinators of flowering plants for successful reproduction [56], [57], [58], [59], [60]. Nectar from flowering plants attracts pollinators to forage [62], [63] pollen [63], [64] and/or thermal rewards [61], [65], [66], [67], [68]. Food and Agriculture Organization (FAO) of the United Nations on 'Potential effects of climate change on crop pollination' reports that insect pollination is vital for about 35% of global food production for human consumption [69], [70], [71].

To cope up with climate change plants have to adapt to changing local climatic conditions and that will affect plant-pollinator relationships in unanticipated ways. Changes in the composition of plant and pollinator assemblages is likely to occur in many locations due to climate change as species in the tropics appear to be living at or near their thermal optimum temperature. Migration of some species towards cooler areas may also be expected as a result of warming of the locations [21]. Future global warming may have impact on insect pollinators behavioral responses and the pollination services they offer to our crops.

The foraging behavior of insect pollinators is environmental dependant viz., commencement and cessation of foraging activity, frequency of their visitation on flowers and pollinators abundance per meter square area [2]. The activities of insect pollinators are influenced by some climatic variables that include temperature, humidity, light intensity, solar radiation and wind speed [72], [73]. However, different pollinators can respond to these variables differently.

Each species of social bee has a microclimatic 'window' within which foraging flight can be sustained [81]. Bees, the most important pollinator's worldwide [1] are ectothermic and require elevated body temperatures for flying. The extent of their activity is determined by thermal properties of their environments [83]. For example, foraging by bumblebee can start and peak at temperatures lower than honey bees [74]. Honey bees can maintain a fairly constant thorax surface temperature (33.7–35.7ºC) at air temperatures between 10-27ºC [75], but continuous flight at ambient temperatures below 20ºC increases the risk of thoracic temperature falling below the minimum required for flight[76]. Bumblebees have large body mass and are well insulated with long and dense setae [77], allowing them to retain heat when foraging in cool conditions [78]. However, this may lead to overheating in warmer conditions [78].

Thus activities of insect pollinators may get disturbed on account of increase in temperature, irregular rainfall pattern, relative humidity and other different environmental factors.

Pollinator behavior along with their abundance may also get altered by climate variability. For example, for flight honey bees maintain adequate thoracic temperatures, they may spend time for shivering [79]. Therefore, as air temperature decreases, time spent for shivering as opposed to foraging may increase. If temperature fall below10ºC then bees are unable to generate enough heat for flight [80]. Likewise, Dipteran pollinators may spend more time in sun basking to absorb solar radiation than to sustain flight due to decreasing temperatures. [82].Thus thermal constraints may limit the pollinating effectiveness of bees as it influences flight activity.

Response of Pollinating insects to climate variables may have significant implications on crop pollination. This effect may alter pollinator diversity i.e. pollinator assemblages may change in numbers and proportions of pollinating species than are currently present. As the effect of climate change on pollinators depends upon their thermal tolerance and plasticity to temperature changes, therefore there is an earnest need to investigate the thermal tolerance of important crop pollinators. Negative effects of drought and water stress on the growth and yield of the crop has been reported but their impacts on pollinators are less well understood. Also, a detailed investigation of the composition of each pollinator community is also needed.

II. CONCLUSION

Climate change can enhance or disrupt biological systems, but currently, little is known about how organism reacts to the climate change and how their plasticity may facilitate adaptation to localized climate variation. Literature reveals decrease in the productions of crop due to the negative effect of climate change on pollination which may further leads to serious global food security problem. It is also reported that the native biodiversity and trophic relationship will also get altered which may results in lowering the crop production. Therefore to increase yield of crops, it is very important to provide precise information on the potential impacts of different climate change on crop pollination and their pollinators.

On a larger scale, changes in temperature, disturbances on rainfall pattern or any other environmental change over the entire season may alter the abundance, diversity and foraging behavior of pollinators. Hence climate change causes very serious impact on insect pollinators and flowering plants. As temperatures increase and exceed the thermal tolerance levels of the species, distributions of species are expected to shift towards the poles and higher altitudes. Many studies have already found pole ward expansions of plants and animals as a result of climate change.

Crop species and managed pollinators may easily be transported and grown in more suitable areas. However, moving food production to new areas may have serious socio-economic consequences. In addition, wild pollinators might not be able to follow the movement of crops. For that reason conservation measures will be needed to prevent the loss of this rich genetic diversity of insect pollinators and to preserve ecotypes that are so valuable for world biodiversity along with a feasible risk evaluation strategy to plan against losses of pollination services due to climate change.

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