Article

Impact of Climate Change on Insect Pollination

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ABSTRACT

Self- and Cross-pollinations (Auto- and Allogamy) are the two kinds of pollination in flowers. Cross-pollination is brought out by external agents like insects, rodents, bats, birds, wind and water. The Entomophily or insect pollination which was evident from the 100 million year old amber fossils is of wide occurrence in modern time. Around 80% of the modern flowering plant species are insect pollinated. Insects such as Bees, Butterflies, Beetles, Thrips and Flies are the well known pollinators of wild, agricultural and horticultural plant species. The Climate Change caused by accumulating atmospheric Green House Gases (GHG) such as Carbon-dioxide, rising Global Temperature, abnormal precipitation and drought, etc. seem to change the phenology of both flowering plants and insect pollinators thereby reducing the efficiency of the latter in pollination. Further, reductions in the insect population and flower production, the other impacts of climate change, will have a direct effect on pollination. The adverse consequence of the pollinatory role of the major group of pollinators, the insects, will certainly have a more negative impact on the agricultural, horticultural and other plant production and that will in turn affect the global economy in future.

Key words: Cross-pollination, Entomophily, Green House Gases, Phenology.

Introduction: Self- and Cross-pollination (Autogamy and Allogamy) are the two kinds of pollinations seen in flowering plants. In cross-pollination external agents like wind, water and animals play a crucial role in transporting pollens from the anthers (male sex part) of a flower to the stigma (female sex part) of another flower. Among the pollination by external agents insect pollination (Entomophily) evident from more than 100 million year old amber fossils of Cretaceous period(Nathan, 2012) is of wide occurrence in modern time. Insect pollination contributes to the success of many modern plant species. Insects such as bees, butterflies, moths, beetles, thrips, mosquitoes and other flies are the well known major pollinators of wild, agricultural, sylvicultural and horticultural plant species. The flowering plants for their need of pollination and their insect pollinators for their need of food are considered to be co-evolved for their success over a long evolutionary period. In the present review the economic values and the impact of climate change are discussed with reference to insect pollination.

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Economic value of Insect Pollination:

To reproduce successfully about 90% of higher plants depend upon animals to pollinate their flowers (Nabhan & Buchmann, 1997). Among the animal agents insects are the most important groups that provide this ecological service to the plants (Proctor *et. al*., 1996). More than 20,000 species of wild bees, domesticated bees and other well known pollinators are responsible for producing 235 to 577 billion US$ worth of annual global food (FAO, 2016). In the past 50 years a threefold increase in the global agricultural food production was evident due to pollination by insects (Entomophily) and other animals (Zoophily). Besides food production, Entomophily and Zoophily significantly contribute to the production of bio-fuels, fibers, medicines, life stock forage, fodder, etc. It is further estimated that 80% of the world's 2, 50,000 flowering plants contribute 15% to 30% of the global food supply and these plants are mainly pollinated by insects. From 1, 00,000 to 3, 00,000 animal species mainly including insects are involved in this major task of ecosystem service contributing a global economic value of pollination service to a tune of 200 billion US$ and 40 billion US$ in United States alone(CST-NC, 1999-2014). As per the United States Department of Agricultural Report (2018) the annual value of pollination service provided by honey bees in US is 15 billion US$ and the same is computed as 655.6 million US$ in the case of commercialized bees byBond, et. al., (2014). In Europe 84% of agricultural crops are directly pollinated by insects particularly the bees (Williams, 1994). Wild bees are also known to extensively pollinate large array of crops (Kremen*et. al*., 2002; Greenleaf and Kremen, 2006; Winfree*et. al*. 2007, 2008). The worldwide economic value of direct insect pollination was found to be 153 billion € (Gallai *et. al*., 2009) in 2005. This forms 9.5% of the total value of global production of human food. The fore said benefit of pollination is under the risk in recent time and that is due to the decline of wild and commercialized bees along with their host plants in Britain and Netherlands (Biesmeijer*et. al*., 2006). The most probable reason for the decline in pollination services by insects and in particular by bees are predicted to be the imminent cause of the change in global climate.

Impact of Climate Change on Insect Pollination:

Climate change is known to certainly cause in Entomophily the Phenological conflicts between insect agents and plant species, adverse changes in their biodiversity, survival and population density.

Phenological Conflicts:

Phenology is the periodic plant and animal life events that occur in relation to annual cycle of climate conditions. Plants like trees with better insulated root system are not easily affected by ambient seasonal temperature fluctuations due to climate change and they bloom at the normal period of time. On the other hand changes in the climate definitely affect the pollinators by delaying their larval maturation into adults and population build-up in normal time. This conflict is known to reduce the incidence of pollination and subsequently the crop production (Esaias, W., 2007). As a typical example, warm temperature is essential for broods of honey bee larvae to survive better and to mature into enough population of workers for effective pollination. In temperate countries climate change causes an early spring cold snaps that kill many of the developing worker bees and causes a delay in their population build-up. This will impede the pollination even though the normal blooming occurs in unaffected plants (Esaias, W., 2007). On the contrary, in some parts of Europe unusually high spring temperature accelerate hatching from egg and adult emergence from cocoon of butterflies and other insect pollinators when enough blooming is not there in plants to provide nectar and pollen (Berwyn, 2018).In recent time in temperate countries including United Kingdom and United States global warming causes an earlier onset of spring. This results in too early blooming of plants when the insect pollinating agent's populations have not built-up enough for normal incidences of pollination and plant reproduction(Dell'Amore, 2013; Amano *et. al*., 2010)According to Inouye (2006) the climate change disturbing the timing of blooming and emergence of overwintering insect pollinators will irrevocably hamper their phenological intimacy that co-evolved over the past hundreds of years. Further, his studies on mountain ecosystem and pollination ecology at Colorado Rocky Mountains show that in high altitudes the adverse effect of climate change in pollination is more drastic.Timing of flowering is advanced as a result of earlier onset of increased ambient temperature and snow melting. Such abundant occurrence of flowers without enough density of pollinators including insect may result in the failure in survival and reproduction of both the pollinators and the plant species concerned. Because of this phenological conflict in the long run a possible extinction of both the partners of pollination is predicted (Inouye, 2006).

Climate change can generate a mismatch in the seasonal timing of interacting plants and their pollinators owing to species specific shifts in their phenology (Bartomeus *et. al*., 2011; Visser & Both, 2005). Forrest and Thomson (2011) from their investigation on phonological responses of insect pollinators and their flowering host plants in Rocky Mountain Meadows suggested higher threshold ambient temperatures for development and diapause termination in insects than those required for blooming in plants. Hence, plants' response is earlier than pollinators like bees and wasps. They further proposed that cues from local environmental changes are the primary causes of species specific phonological changes between pollinating partners. Rafferty and Ives (2011) from their studies on flowering phenology of 14 perennial plant species with their pollinator activity showed that the phonological mismatch in plant-pollinator mutualism does not occur in all cases. This is because of the fact there may be matched phonological responses either by shifting or by non-shifting seen in the pollinating partners due to climate change (Rafferty & Ives, 2011)). In the same way a buffered phenological responses in making normal quantity of pollination is also possible when interacting pollinating partners in this regard evolved similar responses to environmental changes (Elzinga *et. al*., 2007). From their studies on 10 insect species, visiting wide range of flowers in spring showingno phenological mismatch in past years, Bartomeus *et. al*. (2011) predicted that in future if the global warming continues in the same quicker phase as it is seen now, a significant mismatch in this regard would occur between partners of pollination hindering the crop reproduction. An extensive analysis of mutual pollinating interactions on 1420 pollinators and 429 plants by Memmott*et. al*. (2007) leads to the prediction that definite phenological shifts may occur due to climate change and that could cause 17-50% reduction in floral resources to pollinators. This would in turn be a main reason for the extinction of pollinators by decreasing their diet breadth with a subsequent end of their crucial pollinating interaction with the host plants leading to the loss of crop production. Global Warming Simulated Model studies conducted to assess the impact of climate change on the pollination services of bumble bees reveal that the warming can decrease the entire period of pollinating interactions (Memmott*et. al*., 2010).

Impact on Insect Biodiversity and Population:

Carvell*et. al*. (2006) reported that the bumble bees (*Bombus* spp.) populations are badly affectedin agro-ecosystem because of climate change causing a decline in their forage availability. Similarly the overall bee diversity including solitary wild bees is known to decline in large part of Britain and Netherland (Biesmeijer, *et. al*., 2006) and only six species of bumble bees are known to commonly occur in United Kingdom out of 22 extant species (Williams, 2007)It is also predicted that extreme changes in cold and warm climates can adversely affect the distribution of warm- and cold-adapted bumblebees (Williams *et.al*., 2007; Williams& Osborne, 2009). Likewise reductions in abundance and geographic range have been documented for bumble bee population in other parts of Europe and North America (Williams, 1982, Goulson, 2003). In Southern Colorado Rocky Mountains it is observed that early increase in ambient temperature with snow melting triggers a warmer and drier condition. This results in decreased amount of wild flower blooming with a subsequent decline in pollinator populations including bees (Aldridge et. al., 2011). Climate change is predicted to be the possible contributor of a mismatch in blooming time of plants and emergence of bees from hibernation in Colorado Rocky Mountains. This discordance is the reason for bee population reduction (Thomson, 2010). In Sweden a drastic decline in the some bumble bee populations and their pollination services on red clover, an important forage plant, was noticed over the last 70 years causing two fold reductions in seed yield. The above changes in the biodiversity of bumble bee populations would be detrimental to the stability of the forage crops in future (Bommarco, 2011). Reports on native Indian honey bee, *Apis dorsata*, shows a 20% reduction in their population over the past 10 years (Smith, 2010).

Conclusion:

The doubling of CO_2 concentration in earth atmosphere is forecasted between 2070 and 2100 (IPCC, 2001). The doubling of this green house gas is predicted to cause a raise of the annual average atmospheric temperature between 3.5^{o}C and 5^{o}C. The climate change, an imminent impact of Green House gas accumulation in atmosphere, is prognosed to generate disruptions in the mutual purposeful ecological interactions between many insect pollinators and their host plants. In the long run this disruption will seriously cause species extinction in both plants and pollinators by reducing their survival, reproduction and habitat. (Memmott *et. al*., 2010). Ultimately this environmental interference in pollination would definitely produce untoward effects on global economy in terms of food production.

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