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Mini Review

Honey Bee Dynamics in the Face of Climate Change

Sanu Kumar Saha[1]*, Sk Md A Rahman[2], Saon Banerjee[3] and Rahman F H[4]

[1]Subject Matter Specialist (Agromet), Krishi Vigyan Kendra, India

[2]Senior Scientist and Head, Krishi Vigyan Kendra, India

[3]Professor, Department of Agricultural Meteorology & Physics, India

[4]Principle Scientist, ATARI-Kolkata, India

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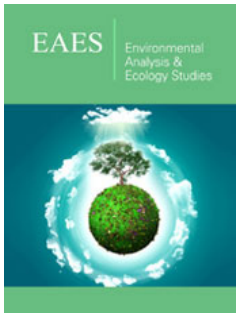

***Corresponding author:** Sanu Kumar Saha, Subject Matter Specialist (Agromet), Krishi Vigyan Kendra, Burdwan, ICAR-CRIJAF, West Bengal, India

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Introduction

Honeybees (*Apismellifera*) and their resource base have been managed to enhance supporting and provisioning services to human kind since ancient times [1]. Many food crops, mostly cross pollinated ones are entomophilous in nature and rely on insects for pollination. Approximately 73 per cent of the world is cultivated crops are pollinated by bees, 19 per cent by flies, 6.5 per cent by bats, 5 per cent by wasps, 5 per cent by beetles, 4 per cent by birds, and 4 per cent by butterflies and moths [2]. The pollinators in turn benefit by obtaining floral resources such as nectar, pollen or both. This mutualism has evolved over centuries and been helping both natural terrestrial ecosystems as well as man-made agro-ecosystems. However, of late, climate change is putting a negative influence on the lives of people and the population of honey bees are not an exception to the pernicious act of mother nature. In the present literature, an attempt has been intended to briefly summarize the variability in the population dynamics, pollination activities, any behavioural and physiological changes in the wake of horrible climate change conditions.

Honey Bees as Pollinator in Agriculture

Pollinators such as bees, birds and bats affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide [3]. Honey is an important component of the world's economy and trade of natural honey was worth US$ 3.3 billion in 2011 [4,5]. Over the last half century, there has been a steady increase in the global production of honey. The average productivity of each hive has also increased. The growth of production has outstripped the increase in bee colonies by more than a factor of two [6]. Furthermore, the value of pollination by the honeybee may be worth from 30 to 100 times the value of honey and beeswax combined [5]. Globally, the value of insect pollination may exceed $300bn [4,7] with the honeybee perhaps responsible for 80% of crop pollination overall and 100% in some intensive orchard crops.

Climate Change and its Possible Impacts on Honey Bees

Climate change is a global phenomenon and it may be a change in average weather conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). The globally averaged temperature data shows a warming of 0.85 °C over the period 1880-2012 and is likely to increase further by 0.3-0.7 °C by 2035 [8]. India is fortunate enough to have all four major honeybee species viz., *A. cerana, A. dorsata, A. florea and A. mellifera* (an introduced one) which have become an integral part of Indian agriculture and

rural livelihood both as pollinators and honey producers. However, in recent times, there has been a growing concern about declines in the natural populations of honeybees. Among different factors responsible for bee decline are habitat loss and fragmentation, chemical intensive agriculture, invasive species and climate change [9]. Climate change appears to be a major concern for agriculture in general and may also have worrying implications for beekeeping. Climate change can influence honey bees at different levels. It can have a direct influence on their behaviour and physiology. It can also alter the quality of the floral environment and increase or reduce colony harvesting capacity and development [10] and can influence the development cycle.

Behavioural Changes in Bees and Climate Variability

Climate change is thought to be one of major threats to pollination services [11,12]. The IPCC documented the increased global temperatures (1.1-6.4 °C by the end of this century), a decrease in snow and ice cover, and changed frequency and intensity of precipitation as the major consequences of climate change [8]. An excessively dry climate, which reduces pollen production and impoverishes its nutritional quality, would adversely affect bees of that habitat [13]. Behavioural responses of bees to avoid extreme temperatures could significantly impacts pollination services. The time taken for thermoregulation at higher temperatures comes at the cost of foraging. With increase in temperatures, the efficiency of pollen removal and deposition will change and pollinators are at risk of over-heating especially in regions where ambient temperatures are high and climatic conditions are stable. On the contrary, during the lockdown period, the quality of air improved significantly and the abundance of flora in the surrounding and a peaceful environment kept the bees busier and filled up the hives with honey in a quick time. As compared to the usual 15 to 20kg honey collected in each bee box, the quantity rose significantly to nearly 40 kg per box during the lockdown [14]. This is because of little pollution and almost zero use of pesticides in the crops during this period, the quality of honey also improved as bees collected pesticide-free nectar and pollen from the flowers.

Response of Honey Bees to Enhanced Temperature & CO_2 levels

Climate change is causing temperature shifts which are leaving bees unable to pollinate in time. Bees are severely vulnerable to extreme weather and climate change has caused flowers to emerge and bloom earlier. Because bees are unable to adapt to the changing climate, they are unable to pollinate flowers and, thus, do not obtain nectar for their hives to use during the harsh winter months. As average monthly temperatures rise, flowers bloom earlier in the spring, creating a potential mismatch in seasonal timing between when flowers produce pollen and when bees are ready to feed on that pollen. Even a small mismatch of three to six days could negatively affect bees' health, making them less likely to reproduce and less resistant to predators and parasites. Research from the Environment Protection Agency shows that CCD (Colony collapse disorder) is linked to changes in bee habitats and malnutrition, both of which are indirectly caused by climate change [15]. In addition, climate change allows invasive species to take over bee hive, spoil stored food, and disrupt many processes within these hives, causing a further decline in bee populations. It is difficult to estimate the direct impact of enhancing CO_2 levels on bees however, indirectly; elevation in carbon di-oxide in atmosphere is expected to modify ratios of carbon and nitrogen in plant tissues, possibly leading to changes in nectar composition [16].

Extreme Climate Events and Pollination

Extreme climate events might have detrimental effects on both crop plants and pollinator populations. High temperatures, long periods of heavy rain and late frost may affect pollinator activity either by reducing population sizes or by affecting insect activity patterns. High precipitation may limit bees foraging activity. Optimal foraging conditions for pollinators are sunny days with low wind speed and intermediate temperature. The probability of extreme climate events may change in the future. The extreme weather conditions in association with warming of earth's climate may put lethal impact on pollinators like honey bees already stressed from climate change. Studies also showed that the warming of earth's environment has resulted in early blooming of plant species an average of a half day earlier each year and as a result, some plants don't get the chance to pollinate and the bees remain hungry for most of the period. Study has revealed that the reproductive ability of honey bee pests can be enhanced by hot and humid conditions [17]. Risk assessments should be conducted to better understand the changes in frequency of extreme climate events and minimize the effects.

Pest Species, Pesticides and Pathogens

Pests and diseases have been reported to increase due to impacts of climate change to the areas where they never had been previously reported [18]. Climate change will affect various types of pests in different ways [19,20]. Increased temperatures may speed up pathogen growth rates. Warming may also favour the growth rate and geographic range of many crop-attacking insect pests [21]. Increased demand for control of plant pests often involves the use of pesticides, which can have negative impacts on human health and the environment [22], including ecosystem services such as pollination. Pollinators like honey bees are also negatively affected by predators, parasites and pathogens. Natural movements of pollinator species and exchanges of domesticated bees among beekeepers will bring them into contact with new pathogens. Pests and pathogens may find new potential hosts [10]. Thus, changes in optimal bioclimatic conditions may be a stressor for the honey bees, leading to increased vulnerability to parasites [23]. On the verge of increased climate change complexities, some patterns of the honey bees and their parasitic mite are expected to be influenced. Likewise, the small hive beetle is a parasite of honey bee colonies. Future scenarios of global warming project a vehement increase in climatic suitability for SHB and corresponding potential for invasion, especially in the temperate regions of the Northern

hemisphere, thereby creating demand for enhanced and adapted mitigation and management [24].

Conclusion

It is indeed tough to find out the overall impact of different aspects of climatic variability on bee activity and their pollination services which are relatively novel to us in a single attempt. However, to formulate any specific adaptation strategy against climatic phenomenon, it is important to derive the variability in bees population and their interaction pattern with different crop plants. Scientific literatures are quite limited regarding how the bees are going to react in terms of pollination, which specific plant will suffer, which phenophases will be affected most in the face of relentless climate change scenarios. Realization of the sensitivity of crops plants and their associated pollinators towards temperature variability is also under assessment. On the other hand, among different species of honey bees, the Asian species in restricted mainly in Asian countries whereas, the European one is found in various parts of the world. This indicates continuous variability in different weather elements will affect the Asian species mostly as compared to the European one which has shown greater adaptive capacity due to its genetic variability to adapt to climate change. Therefore, we recommend the growing of honey bees in hives (artificial)should be increased throughout the world, which not only conserves the traditional indigenous bee species but also could become a possible source of livelihood security for the farmers. However, more studies and experiments still need to have prioritized in coming days to remove the knowledge gap between the sensitivity of bees towards climate change and subsequent influence of it on the basic ecology of their pollination services vis-à-vis crop production scenarios worldwide.

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