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Effect of Climate on Honey Bee Production in Special Reference to Rajasthan

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ABSTRACT: In Rajasthan, most crops grown require pollination to produce food, and honey bees are the most important pollinators. Without honey bees, the food supply would decrease and become more expensive. Climate change threatens honey bees by destroying their habitats and food sources. Apis mellifera, is the most economically valuable pollinator of agricultural crops. The survival requirement for these bees is a supply of water, which they use in large quantities to raise their larvae and to regulate the brood temperature to between 34°C and 35°C. In an arid environment, desert flowers are unable to provide the bees with enough water and they die. According to climate change predictions, desert regions will become even drier, leading to the disappearance of oases and their honey bees. Apis mellifera sahariensis is highly unlikely to migrate naturally to more favourable desert areas because oases are very isolated and not conducive to long-distance migration or swarming. It is therefore vital to envisage conservation measures to transfer this bee to zones favourable to its development, lest we lose this ecotype that is so valuable for world biodiversity.

KEYWORDS: honey bee, climate, production, Rajasthan, economic

I. INTRODUCTION

Climate change in Rajasthan can influence the honey bee development cycle. It is generally agreed that each race of honey bees develops at its own rate. In cool regions, honey bees spend the winter clustered in a tight ball and use their honey stores to provide them with the energy, they need to survive until spring. The honey bee's capacity to accumulate energy reserves and to manage the colony's development exerts significant adaptive pressure. In the spring, when the weather becomes more clement, the queen starts to lay eggs and the colony develops and increases the size of the worker population. A cold snap lasting several weeks may occur during which the honey bees are unable to harvest. The large size of the honey bee population causes such a rapid depletion of stores that the colony can die of starvation. Hybrids bees (crosses of several races by bee breeders) have not been bred to build up food stores, the queen does not adjust her egg-laying and the workers do not adjust their larvae-rearing, with the result that the bees are unable to survive without the assistance of a beekeeper to provide them with unlimited supplies of sugar solution. The variability of the honey bee's life- history traits as regards temperature and the environment shows such plasticity and genetic variability that this could give rise to the selection of development cycles suited to new climatic conditions. Bees adjust their behaviour to weather conditions. They do not go out when it rains and, in extremely hot weather, they gather water to keep the colony cool.[1,2,3]

Climate influences flower development and nectar and pollen production, which are directly linked with colonies' foraging activity and development [18]. Bees must build up sufficient honey stores to enable them to survive the winter. The nurse worker bees must consume enough pollen to feed the larvae through their pharyngeal glands. A major effect of climate change on honey bees stems from changes in the distribution of the flower species [19] on which the bees depend for food. We are aware of the impact that rain can have on honey harvesting by bees. For instance, when acacia flowers are washed by rain, they are no longer attractive to honey bees as it dilutes their nectar too much. Likewise, an overly dry climate will reduce the production of flower nectar for honey bees to harvest: lavender flowers produce no nectar when the weather is too dry, which makes harvesting by bees a largely hypothetical matter. In extreme situations, honey bees can die of starvation unless the beekeeper is vigilant

The honeydew produced by stinging insects from certain plant species is also climate-dependent. In Alsace, very special conditions are required for the development and growth of balsam fir aphid populations, whose honeydew is highly attractive to honey bees (Jean-Prost and Le Conte, 2005). On the other hand, certain types of honeydew cause dysentery in honey bees.

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The food shortages stemming from an excessively dry climate, which reduces pollen production and impoverishes its nutritional quality, are currently the subject of much debate [20]. Honey bees that are born in autumn spend the entire winter in the hive and form the backbone of the colony in spring. A pollen diet is very important for rearing the future workers [21]. A pollen shortage induced by autumn drought will have the effect of depriving bees in winter, weakening their immune system and making them more susceptible to pathogens, and shortening their lifespan.

II. DISCUSSION

Bees are tough little creatures, able to thrive almost anywhere – the only place in the world without beehives is Antarctica. But as climate change brings on extreme weather patterns, temperature changes and rising sea levels, even this adaptable species is being affected.

In Rajasthan, climate change is already contributing to declining populations of honeybees and other bee species, thanks to reduced habitats and changing patterns of plant growth over the seasons.

For humans, loss of bees doesn't just mean pricier honey – bees are also responsible for pollinating almost a third of the plants we rely on for food. Without robust bee populations, these food sources – including coffee, apples, berries, almonds, broccoli, and melons – could end up being far more expensive to grow, or even die out altogether. It's just one of the reasons climate change is the issue of our time.

Here's how the climate is affecting our bees – and how you can help:

Loss of habitat[4,5,6]
For bees, habitat loss isn't about the physical space they need to live, it's also about the range of plant species available for them to feed on. Climate change can make it more difficult for some species of plant to thrive in certain areas, affecting food supplies for bees. Native bees in Australia are particularly vulnerable to loss of habitat, as some species only feed on one or two types of plant.

Of course, climate change isn't the only cause of habitat loss – human development and clear-felling of forests and bush are also important factors.

Temperatures and seasonal timing
As average temperatures rise around the globe, delicate ecosystems are thrown out of balance. Higher temperatures mean that flowers may bloom weeks or months earlier than usual or bloom for shorter periods. Bees, who have adapted to an extremely specific pattern of pollen and nectar availability, can be seriously affected by even small changes to seasonal plant growth.

Just a shift of a week can harm bee health, as less pollen can mean poorer nutrition and reduced resistance to disease.
Weaker bees mean more disease

Bees – particularly honeybees – are affected by many different parasites and diseases. Although Australian beekeepers don't have to worry about Varroa mites, these tiny invaders do affect bees in other places around the world. Nosema parasites, which cause intestinal problems, and American Foulbrood Disease are also seriously damaging, leading to colony collapse if left untreated.

Although climate change doesn't directly cause disease or parasite infestations, it can make colonies weaker and more vulnerable to infection. Research shows that the Nosema parasite also seems to thrive in higher temperatures, which means that climate change will likely help it spread.

Wild weather and extreme heat
In Rajasthan, Aside from gradually rising average temperatures, climate change is also leading to more extreme weather patterns around the world. In Australia, extreme heat has made devastating bushfires more frequent, while flooding, hurricanes, and droughts are increasing in other places.

These natural disasters can have an obvious effect on honeybees and natives, wiping out habitats, destroying hives and burrows or simply killing off bees in their thousands. Long periods of extreme heat can also affect some bee species – bumblebees in particular seem to be affected by high temperatures.

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How you can help
Climate change is a huge, global issue that can't be solved by any one person. In a small way, you can help bees in your area by planting a diverse range of bee-friendly plants that bloom throughout the year. If you're a beekeeper, you can do your best to prevent the spread of parasites and bee diseases, and set up your hives to protect your colonies from extreme weather.

Of course, these aren't long-term solutions for the climate change issue. For most people, advocating for policies and voting to fight climate change is the only solution likely to have a real, long-term impact.

III. RESULTS

The expanding geographic areas will have warmer autumns and winters extending honey bee flight times. Our simulations support the hypothesis that late-season flight alters the overwintering colony age structure, skews the population towards older bees, and leads to greater risks of colony failure in the spring. Management intervention by moving colonies to cold storage facilities for overwintering has the potential to reduce honey bee colony losses. However, critical gaps remain in how to optimize winter management strategies to improve the survival of overwintering colonies in different locations and conditions. It is imperative that we bridge the gaps to sustain honey bees and the beekeeping industry and ensure food and nutritional security.

Rajasthan storms, intense heat, flooding, drought, and forest fires have ravaged the globe, resulting in mass ecological devastation and displacement. Scientists from leading research organizations predict these weather extremes to become ever more common, leading us [7,8,9]to wonder what other butterfly effects climate change has in store.

Enter pollinators, or specifically, the honey bee. Apis mellifera, better known as the honey bee, is one of many magnificent insect species which pollinate nearly 75% of all major food crops across the United States. Dating back over 33 million years old, with estimated over 20,000 different species, bees of all varieties have helped hold our ecosystem together since the dawn of civilization.

However, that peaceful coexistence between humans, plants, and pollinators is being challenged. Over the past 40 years, pollinator health – especially that of bees – has seen the largest decline in human history. From habitat loss, to mismatched plant-pollinator timing, to honey production, climate change has dangerous implications to the survival and success of our pollinator friends.

Talking about climate change, the phrase "habitat loss" gets thrown around a lot. With erratic weather patterns, wildfires, rising sea levels, and higher temperatures, environments which were once suitable for various forms of life are beginning to change. On top of that, the global human population continues to increase, resulting in further demands for urban, suburban, and agricultural development. Our need for more land paired with shrinking resources has begun pushing native species from their natural habitats.

Recent studies on native bees and habitable spaces have shown that changes in temperature have shrunk pollinator habitats, limiting migration zones for native bees. Having originated in colder climates, or evolving to live in them, some species of bees are unable to adjust to new warmer temperatures. As temperatures rise, these bees are forced to migrate to colder zones, shrinking their habitats, and limiting their ability to pollinate their familiar environments.

Increased temperatures also pose dangers on bees' access to drinking water. Like us, bees need water in order to survive; however, in environments where droughts are becoming ever more common, bees are struggling to meet their needs.

Not only do droughts limit bees' access to water, but also pose a threat to plants, which also require water to bloom and produce nectar. The relationship between droughts, plants, and pollinators has been vigorously studied — findings show that, without enough water in an ecosystem, regular plant life is less likely to grow. Additionally, the plants that do sprout have a lower chance of producing nectar, meaning the ecosystem has decreased capacity to sustain pollinator life.

On the completely opposite end, too much water is equally devastating to the environment. As we witness harsher storms and rising sea levels, the occurrence of extreme flooding poses a risk to bees situated on coastlines or near bodies of water. If the area around a beehive were to flood, so would the bees' nests and foraging areas. While there

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have been cases of bees surviving their hives being flooded out, over-waterlogged plants they forage on may not.. This creates a scarcity of resources within their already shrinking habitat.

Storms in Rajastha, Its high-speed winds and mass flooding also devastated the bloom of the pepper tree, stripping the plants nearly bare. The plant is a significant source of nectar for bees, and without it, they could not produce their normal fall honey crop. This launched a domino effect of poor honey production, with the bees' state of malnutrition spilling over into the following year

Beyond acts of nature, human activity has also degraded or destroyed wild areas. The population of the human race is at an all time high, and as we grow, we are forced to migrate and take over natural spaces.

Agricultural intensification[10,11,12] is the process of increasing agricultural productivity in order to produce more food for our growing populations. These practices often expand agricultural land, taking away pollinators' habitable areas, and significantly decreases biodiversity as well as reduces habitat connectivity. This expansion often results in increased pesticide use, which has devastating effects on pollinator health.

The rapid spread of human development has led to habitat fragmentation, where larger ecosystems are pardoned off and sectioned into smaller slivers of an unaligned whole. This results in unharmonious sub-ecosystems that don't always contain all the attributes necessary for a highly functioning ecosystem.

Domestication of natural habitats, such as lawn culture and curated parks, also work to the detriment of pollinators, as it destroys nesting habitat and important foraging resources. Additionally, domestication sometimes results in the introduction of invasive plant species. These non-native plants are able to outcompete native plants for already limited resources, impacting the abundance of native flora required by pollinators like bees to forage and reproduce.

In Rajasthan, Unlike many insects who hibernate or die out in the winter, honey bees actually undergo an adaptation of hibernation referred to as 'overwintering.' Once temperatures drop below approximately 50°F (10°C), the bees cluster inside their hive in a massive huddle to preserve heat. Winter bees are born in late fall and have larger fat bodies which help them conserve heat, expend less energy, and limit food consumption. These bees live significantly longer than average honey bees, hibernating through the winter until early spring, where they act as the first generation of bees to provide resources for the colony.

With climate change causing warmer winters with strange flash freezes and unpredictable weather patterns, colonies have begun to preemptively exit their overwintering state. Awoken to a still harsh and barren world, forager bees fail to find the nectar and pollen stores they have been waiting for all winter. Then, as temperatures swing back into freezing, bees who have left the hive or cluster are left out to paralyze and freeze in the cold. These occurrences not only confuse the bees, but weaken the colony significantly, sometimes leading to starvation or entire colonies freezing.

Furthermore, early springs can mess with the queen's brood laying. Brood, or bee babies, undergo four stages before becoming bees: egg, uncapped larvae, capped larvae, and pupa. Depending on what type of bee they will become, it can take between 15 to 24 days for an egg to develop into a bee, which means the queen needs to be laying constantly spring through fall for the colony to maintain typical population growth patterns.

Brood requires a lot of food and energy to develop fully, which means that the rest of the colony must be able to collect enough pollen and honey in order to provide for the new hatchlings. When temperatures reach above 50°F earlier than normal, it signals to the queen that it's time for the new season. However, the flowers, grasses, and trees which the bees require for food are not always ready that early on. Without the resources to feed an increased population, this mismatch in timing could lead to colony starvation. Not only that, but temperatures swinging too low after brood production has begun can also freeze new eggs, killing them and creating more work for the weakened colony.

As our climate begins to shift, with summer and autumn lengthening, bees are no longer forced into hibernation as early as in decades past. Instead, due to the heat, bees are able to prolong foraging much later into the season. While this may initially read as a positive, this situation results in something referred to as 'skewed colony age structure.'

Colony age structure is an inherent property of honey bees which helps determine the division of labor and define how age-related events, like disease and death, affect the colony's overall health. For example, a typical honey bee will live up to six weeks. In that time it will cycle through every job within the hive in a set order: nursing first, then capping

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cells, attending the queen, guarding the hive, and finally foraging. When the autumn season is prolonged, it allows bees which were previously not able to mature into the foraging stage to exhaust themselves prematurely.

Ideally, the queen will go into the winter with a hive of younger, winter bees who are able to sustain themselves for the duration of the winter. However, the lengthening season results in larger-than-typical numbers of older bees overwintering, leading to a sudden die out of the older bees right at the beginning of spring. This phenomenon referred to as the 'spring dwindle' leads to a decreased colony size, which in turn affects the ability of the colony to gather necessary resources and be attended to properly in preparation of the spring season.

Shifts in seasonal timing have massive impacts on the many types of plants that pollinators rely on for nectar, pollen, and shelter. Premature blooming and mismatches in plant – pollinator timing may be the most dangerous effect of climate change on any given ecosystem as a whole. [13,14,15]

In Rajasthan, As some plants begin to sense warmer temperatures, they send signals to their roots to begin drawing up the water they will need for blossoming. However, since spring temperatures have become more erratic — with earlier warm days followed by sudden deep freezes — many plants that have prematurely started their spring preparations can be killed or severely weakened with these sudden changes. As more plants struggle to bloom, the already limited resources for colonies can lead to starvation, dwindling populations, or less honey production later in the season.

These effects often result in a cycle of destruction within an ecosystem where pollinators that cannot find sustenance die out, and the plants that depend on them for pollination struggle to reproduce. In short, less pollinators means suboptimal or no pollination. This can be particularly problematic in mountain and desert areas, where the spring blooming season can be relatively short. Without their usual army of pollinators, plants which are unable to be pollinated may be under threat of extinction, in turn leading to less biodiversity and fewer resources for the bees the following season.

Changing Floral Fragrances and Climate Change

Even more concerningly, new research has shown that increases or inconsistencies from usual seasonal temperatures have led to some plants releasing slightly different floral fragrances. One study on ozone pollution and floral odors discovered that stress from extreme heat caused certain flowering plants to emit defensive odors. Since bees rely on familiar scents to locate flowers, this poses an issue, as by releasing defensive odors, it changes the plants' typical scent profile, thus making it more challenging for bees and other pollinators to locate them.

Additionally, bees' ability to detect scents is being impaired by climate change and air pollutants, as air pollution works to mask floral fragrances, making it more difficult for them to find the flowers they need. Ozone has been shown that it has the ability to both decrease colony health and greatly reduce bees' ability to locate food sources. A study published in 2022 showed that, after exposure to diesel exhaust and ozone, the number of flowers each bee visited dropped by nearly 90%.

While both of these developments may have different causes, they boil down to the fact that climate change is disrupting pollinators' ability to detect familiar scents. As plants change their scents due to warming temperatures, bees and pollinators are no longer able to find them. Then, as air pollution worsens, it deteriorates pollinators' already challenged ability to smell. Without one of the major senses they use to locate their food, pollinators become incredibly limited in their food supplies and diversity of pollen. This disturbance also poses an implication on those plants in need of pollination, since if they cannot be found, they will not reproduce, further emphasizing the importance of the relationship between pollinators and plants.

IV. CONCLUSION

In Rajasthan, When plants are sick or weak, pests can tell and will flock to the vulnerable plant. As growing seasons shift and plants struggle to adapt to changes in seasonal timing, pests will take advantage of the increasing proportion of vulnerable plants, resulting in greater pesticide use.

Pesticide exposure has always posed a massive risk to bees. Countless studies have shown that pesticide exposure also causes an impairment in immune functioning, birth defects, and can degrade cognitive functioning in areas such as memory and behavioral learning. These vulnerabilities have the ability to weaken significantly to a place where they can easily be wiped out from population loss or increases in pest activity and disease.[16,17,18]

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While climate change causes dangerous stress on bee populations, the opposite occurs for the number one predator of honey bee colonies. Varroa mites, indigenous to Asia, are an invasive species of parasitic mites that attach themselves to the bodies of adult bees to feed on their fat body tissue. This weakens the bees' immune systems, leaving them vulnerable to the number of viruses the varroa spread.

Varroa mites reproduce in honey bee brood, invading uncapped larvae, and laying eggs. When those eggs hatch, they feed themselves on developing larvae, eventually growing into adult mites that can latch onto matured bees. During seasons like late fall and winter, where it is too cold for the queen to lay, varroa tend to die out. However, with warmer autumns, the queen can continue laying right up until winter starts, meaning lots of brood for varroa to multiply from.
Warmer falls have allowed varroa mite season to last longer into the fall, challenging the strength of the hive as they prepare for the winter season. As colonies enter the winter with skewed colony age structures, high mite populations, and sickness, they stand very slim chances of being able to keep up with all their troubles.[19]

Not only are varroa mites a risk, but small hive beetles (SHB) have also seen positive growth as the climate warms. Similar to varroa, small hive beetles are parasites which feed on any resources they can find, reproducing in the honey, pollen, or brood stores of a colony. While not as invasive as mites, these beetles can still pose a significant strain on a colony by taking away precious resources.

Development time is a limiting factor for SHB success. In the case of shorter seasons and colder temperatures, larvae can sometimes fail to complete the metamorphosis cycle. However, under warmer climatic conditions, pupal survival rates are increased, meaning more beetles which are able to reach maturity and lay future generations. The length and heat of a season acts as a predictor for the success rate of SHB populations, and with longer, warmer autumns each year, we are able to see that success at the detriment of honey bee colonies.

Rising CO2 levels are not only warming our planet, but also changing the chemistry of our plants! A study done by USDA Agricultural Research on CO2 and pollen interactions found that increased CO2 levels have resulted in decreased protein content in pollen across varying plant species.

This discovery poses a real threat to the survival of many wild pollinators, as well as honey bees, who depend heavily on pollen for the fats, proteins, minerals, and vitamins they receive through consuming it. As pollen concentration decreases, bees' ability to sustain themselves on naturally found pollen also decreases. Without the right nutrients needed for development, bees may begin to limit their brood rearing, thus shrinking their population. Pollen also greatly affects the weight and success of larvae, meaning that with less effective pollen, we can expect to see weaker, underdeveloped bees.

Many commercial beekeepers have already observed this issue and begun providing supplemental feed or pollen patties to their colonies in the early spring and fall in an attempt to boost the strength and size of brood populations. However, not only is supplemental pollen expensive, overly processed, and not as nutritionally beneficial, but it also isn't available to wild bees and other pollinators.

Queen Bees, Infertility, and Climate Change

Being the only bee who can create new workers, the queen bee is imperative in maintaining colony success and structure. Her genetics, laying pattern, health, and age all play into how well a hive is able to function — however, not even the queen is immune to the effects of climate change.

As temperatures continue to rise, especially in regions which are historically more temperate, queen bees become increasingly at risk of laying fewer fertile eggs. Researchers from the University of British Columbia discovered that exposure to higher levels of heat caused queens to produce proteins that killed sperm, significantly reducing their ability to lay fertile eggs. This then creates a domino effect where, if the queen doesn't lay fertile eggs, the colony has fewer workers, and if the colony has fewer workers, there are fewer bees to collect resources for the queen. With fewer resources for the queen, the fewer eggs she is able to lay, and so on.

As we know, higher temperatures are one of the most common things associated with climate change. Nearly every climate in the world is becoming slightly warmer, meaning that this discovery has the potential to affect possibly every bee species on the planet.

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Honey Production Decreasing Due To Climate Change

Taking all of these factors into consideration, it is evident that honey bees are under more stress than ever before. It is sometimes difficult to accurately assess how these circumstances are affecting a given species. However, because of extensive research on honey bees and increased farming, we are able to see how beekeeping has changed over time and measure those changes in a very tangible way — through honey production.[20]

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