BioThink E – Magazine, Vol. -2, Issue -3, July 2025
ISSN No. – 3048- 7943
www.biothink.in

Climate Change and Honeybees: Potential threat to pollination in the North Western Himalaya.

Dr Sunita Saklani

*Department of Zoology, Sidharth Govt. Utkrisht College Nadaun, District Hamirpur, Himachal Pradesh, India;

Correspondence author : sunsaki786@gmail.com.

Abstract

Climate is a prominent factor determining spatial and temporal species distribution at a particular place and maintaining biodiversity. However, recent change in climate is the predominant problem that threatens the survival of mankind. The intense impact of climatic conditions on agriculture and horticulture is no longer exceptional due to the threat to different honey bee species, which are essential for the tremendous increase in the agricultural and horticultural harvest and for sustainable development. Although it is clear from the substantial data available from studies conducted that the altered climate causes a direct influence on the bees' life cycles, resulting in a decline in their population and income loss for beekeepers. However, presently, there are large gaps in the available literature regarding the identification, estimation, and quantification of threats posed to the honeybee species. Therefore, this review is conducted to identify the effect of climate change on the *Apis spp.* along with evidence.

Keywords: *Biodiversity, Climate Change, Honeybees' Importance, Conservation.*

Introduction:

Honeybees are considered the main pollinating agent responsible for the pollination of nearly 80% of flowering plants. Their importance as pollinators creates a need to conserve honeybees and their ecological niche (Klein et al. 2018; Potts et al., 2016a). The honey bees, along with other bees, help in maintaining food security by providing pollination services to 90% or beyond crops, out of the total

107 important world crops (Patel et al., 2020); However, wind and self-pollination support 60% production of food around the world (Klein et al. 2007). Honeybees pollinate crops, enhancing not only the quantity but also the quality of important crops like fruits, vegetables, nuts, etc. Therefore, add more valuable and balanced nutrition to the masses and impart food security. The estimated value of honeybees' pollinated crops fluctuates between US$235 US$577 billion a year (Malo, 2021). They help in sustaining the livelihood of farmers and beekeepers by acting as income generators through enhanced crop production and honey and other bees' products.

Honeybees' importance goes beyond agriculture and honey production by conserving biodiversity through pollination of naturally growing flora, besides managed food crops. Most of the naturally growing flora act as nectar and pollen sources to the bees. Due to ecosystem dependency on bees for pollination and heritability diversity, bees are crucial for sustaining biodiversity (Kumar et al., 2024). The decline in bee species could be an alarming signal for the subsistence of most bee-pollinated plant species. The scientists have come to the opinion that 100000 plant species would be in danger of extinction due to the scarcity of bee species in the Mau Forest ecosystem, which additionally alters the optimal functionality (FAO, 2007; Agera, 2011). Therefore, bees are important for maintaining the forest ecosystem. Moreover, the presence of bees in the forest ecosystem restrains people's interference in the area due to the stinging terror of the bees and saves the trees, which consequently allows the ecosystem to thrive at its fullest and conserve the forestland in the vicinity of the apiary location. (Lalika and Machangu, 2008). Bees impart means to gene mixing of plants and create variations in the offspring, and enhance survival adaptability. Bee's role in overcoming the challenge of biodiversity conservation can help in achieving the 17 sustainable development goal i.e no poverty, zero hunger, quality education, good health and well-being, clean water and sanitation, Gender equality, clean and green energy etc. set by United Nations calling for an urgency to ensure the viable and resilient bees species (Patel et al., 2020).

Climate is considered a deciding factor for the spatiotemporal distribution of bee species (Pant et al., 2021). Climate change is a critical issue challenging the survival of the human population across the globe right now. It is an alteration in prevailing weather states, and these alterations have grave consequences on the distribution, physiology, and reproduction capabilities of a large number of species, involving pollinators as well (Weber, 2010; Vercelli et al., 2021). The different components of climate change, such as temperature variation, rainfall, increased carbon dioxide concentration, and dynamics related to the ocean, directly or indirectly impact the biodiversity of flora and fauna of all ecosystems.(Parmesan et al., 2011; Bellard et al., 2012). Directional selection and swift migration are caused by climate change, contribute to the reduction of genetic diversity of the population, and, in turn, resilience and ecosystem functioning can be affected (Botkin et al., 2007). In addition, this diverse impact can influence all the ecological aspects like community interaction, food web, interspecific relationships, and biotic interaction, etc. (Walther, 2010; Gilman et al., 2010). The reaction of certain species to the changed climate has indirect consequences on species dependent on them that are responsive to climate change. Following an investigation conducted by (Koh et. al., 2004), out of 9650 interspecific associations comprising parasites and pollinators are in danger of extinction due to the disappearance of the species on which these are reliant. Therefore, to survive in such extreme change of climatic conditions, the different species have to subsist, adapt, or migrate from one geographical region to another (Maggini et al., 2011). Since the honeybees are prominent pollinators of the most of the natural as well as wild flora, it is no longer exception to have the impact of climate change on the honeybees and keeping in view its importance, it is imperative to analyse the effect of changed climate at present and also predict it for the future. So, the beekeepers, farmers, horticulturists, and policymakers can be aware of potential risks and strategies adopted to combat the effects.

Honeybees are the key species used to enhance agricultural and honey production due to their visitation to natural flora

across the globe (Hung et al., 2018). Climate changes include multidimensional factors having a prominent influence on diseases, predators, parasites, viruses, pesticide uses, and bees visiting floral resources. (Goulson et al., 2015; Vercelli et al., 2021; Zawislak et al., 2019;Varikou et al., 2020). All these components directly or indirectly influence the overall health of the bee species.

The North Western Himalaya, and the Bee species

Honeybees are important pollinators of the Northwestern Himalaya, which extends across Ladakh, J&K, Himachal Pradesh, and Uttarakhand. This region is of utmost importance due to ecological, climatic, cultural, and economic significance. It is inhabited by diversified flora and fauna, including *Apis dorsata, Apis cerana, Apis laboriosa, and Apis mellifera,* the exotic or managed European Honeybee species. The honeybees are considered indispensable for the fragile ecosystem and rural livelihood. The wild and endemic flora includes the various medicinal plants used by the people from time immemorial, and bee pollination, the valuable services, are crucial for the maintenance of native and unique flora, seed and fruit sets, and overall biodiversity conservation. Honeybees in this region significantly enhance the high-value horticulture crops like apples, plums, almonds, peaches, cherries, citrus fruits, buckwheat, and millets etc, and sustain the traditional agriculture system like mixed cropping and forest edge agriculture, and conserve the culture and ethnobiological values. Bees also contribute to ecosystem resilience, bioindicators of habitat, and water and soil conservation through maintaining biodiversity. Despite their value, honeybees in this region are vulnerable to the effects of climate change. Since the Indian himalayan region is climate sensitive region owing to its complex topography, fragile ecosystem and season climatic dependency make it highly vulnerable to effect of global w to arming and climatic shift (IPCC, 2023) The impact comprises temperature rise deviation from 0.5 C to 2C in the last few years retreating the important glaciers, causes erratic rainfall with few but intense in some region and events of cloudburst, flood and landslides resulted in loss of life

BioThink E – Magazine, Vol. -2, Issue -3, July 2025
ISSN No. – 3048- 7943
www.biothink.in

and damage to crops (Kulkarni, 2002; Dimri et. al.,2015). The loss of biodiversity and habitat shifts due to migration of flora and fauna by 20 to 500 metres resulted in compression of habitat and potential loss of species including pollinators (Singh, 2011) Agricultural disruption of important cash crop like apple to higher elevation in Himachal Pradesh and Uttarakhand (Arya et al., 2019) is also the repercussion of climate shift.

Phenological alteration, i.e, shifting flowering times in various plants such as *Malus pumila (Apple*), *Abies pindrow*, and some other species, have been reported due to a rise in seasonal average temperature, erratic rainfall, from the Western Himalaya (Gaira et al., 2014; Chand et al., 2017; Negi et al., 2021; Nautiyal et al., 2020; Masoodi et al., 2018) Furthermore, the forest degradation through unsustainable use impacts climate regulation and the livelihood of people that leading to impairing local economy, specially the agriculture and the tourism, and decreasing its resilience to disaster. (Yadav et al., 2021).

Impact of Climate change on Honeybees:

The Impact of climate change on honeybees comprises direct or Indirect effects. Direct impact influences the behaviour, physiology, reproductive cycle, and habitat destruction and include: thermal stress, humidity alteration, extreme weather events, whereas indirect impact include phenological mismatches, nutritional stress, emerging threat of diseases and pest and predators, habitat loss and degradation, altered floral resources (Giannini et al., 2016; Ali et al., 2023; Hatina and Tautz., 2016).

Thermal Stress

Thermal stress includes increases or decreases in mean temperatures of the atmosphere, which affect the honeybees negatively by impairing health and productivity, and the services of pollination. High temperature raises the metabolic rates of honeybees and shortens their floral visit time. As ectotherms, honeybees increase or decrease their body temperature with the atmosphere. Higher metabolic rates increase heart rate and diminish the energy store faster (Villette, 2020). This restricts the foraging

time of honey bees for collecting nectar and pollen (Belsky, 2019). Rise in temperature affects the ability of bees to reproduce due to the impact on larvae and pupae and resulting in larval mortality and reducing the population of bee colonies (Reddy et al., 2012). The bees need a proper temperature to maintain larvae and pupae, and fluctuations in this temperature can affect the brood badly. Similarly, low chilling temperatures destabilise the cluster (created by honeybees through their wing squeeze to maintain the temperature of the hive), resulting in chilling of brood and larval death (Goulson et al, 2015). The absconding behaviour of bee species is also reported due to an increase in ambient temperature. The native bees, *Apis cerana*, show the absconding behaviour stimulated by a rise in ambient temperature during summer (Partap, U, 2011). Temperature stress also affects the sperm viability of drones and queen fertility. The exposure to temperatures above 40 °C can cause more than 40% of mortality in sperm, and queens are also affected by storing less sperm in spermathecae (Bienkowska et al., 2011). In recent years the Himachal Pradesh has experienced a rise in temperature above 35 °C or approaching 40 °C that can induce stress on drones and queens.

Extreme Weather Events:

Extreme weather events are most common in their frequency in recent times. It includes heavy rainfall, cloud bursts, floods, landslides, Storms, and wildfires, which are extremely intense due to climate change. These events are recurring with greater frequency and intensity because of climate change, and affect the structure of bees' hives immediately. Strong winds or fire may be responsible for the disruption and killing of the hive.

Heavy rainfall, aggravated by fewer available flora, restrains the bee colonies from developing strength of colony by limiting foraging activity for storing adequate honey for overwintering. Hives are also at an aggravated risk if they are exposed or isolated, and influenced by the nectar quality altered by heavy rainfall (Smart et al., 2016). Floods and storms directly affect the bees' colonies by destroying hives and causing the loss of colonies. Severe effects of floods can destroy the habitat of bees, and

susceptibility to diseases may increase (Stabentheine, 2012). Agriculture runoff mixed in flood water contains pesticides and toxins that can influence the health of bees. Floodwaters carrying pollutants such as toxins and pesticides, mixed from agriculture, can influence the health of bees (Simon-Delso et al., 2017). Furthermore, it also increases the stress to bees by disrupting their foraging patterns, resulting in restricting access to floral sources for the bees. (Mishra et al., 2023). Similarly, drought occurred due to climate change, created a shortage of food, and heat stress can weaken the strength of the colonies and decrease immunity to combat the stresses, like diseases and insecticides (Mishra et al., 2023).

Phenology Mismatch

Plant-pollinator interactions are indispensable for maintaining biodiversity and sustainability. Bee species are prominent pollinators responsible for the pollination of the myriad population of native and managed crops. However, change in climate is putting pressure on these important plant-pollinator interactions. The successful blooming of flowers is important for the reproduction of angiosperms. (Ahmad et al., 2021). The phenology of flowers is essential for determining the mutual relationship between pollinators and flowers.(Abdala-Roberts et al., 2007). In the hilly areas, the plant reproductive success is determined by flowering time, which is, in turn, inexorably dependent on nutritional composition, temperature of the soil, and diversity of pollinators present at higher altitudes. (Cornelius et al., 2013; Pellerin et al., 2012; Lessard-Therrien et al., 2014; Ahmad et al., 2021). The beginning and offset of blooming are crucial for a plant's life history and potentially affect the success of pollination (Bucher and Römermann, 2020). The continued and long blooming period encourages the pollinators to visit the plants and therefore, increases the performance of plants (Bucher and Römermann, 2020; Trunschke and Stöcklin, 2017). There is a certain available report that shows the shift in flower phenology of certain plant species from the Northwestern Himalayan region (Rana et al., 2025; Ahmed et al., 2021) that can potentially ramify the plant pollinators' interaction. However, proper

BioThink E – Magazine, Vol. -2, Issue -3, July 2025
ISSN No. – 3048- 7943
www.biothink.in

data on the phenological mismatch of bee flora and bee species is scarce and serves as an area of research. In the North-Western Himalayas, honeybees are crucial for pollination of apples, apricots, peaches, plums, cherries, oilseed crops like mustard, vegetables like broccoli, kohlrabi, etc, in addition to various medicinal plants.

The early and late blooming of bee floral resources due to climate change may not match the active period of honeybees and can interfere with floral visitation and result in food scarcity for the hive. Bees must acquire sufficient food to survive during the winter. Changes in bee floral resources on which honey bees depend for nectar and pollen impact the bees' population significantly. The bee population in that region is stressed by low nutritional content due to reduced pollen production induced by an abnormally dry climate. (Hegland et al., 2009; Stockstad, 2007). Pollen deficit caused by dry autumn leads to suffering of bees in the winter, colony strength decline, and makes the colony more susceptible to infections. (Mishra et al., 2023). Successful pollination of a species is influenced by the blooming timing of crops and available pollinators. Some crops like Mangoes, litchi, guava, and other produce mass bloom for a short duration, which demands a huge population of pollinators for their pollination. The blooming time is shifting due to the impact of climate change. Therefore, pollinators already under climate-induced stress find it difficult to endure these conditions and leading to phenological and distribution mismatches that negatively impact the involved species. Mismatches reduced the insect visit to the plant and pollination, whereas pollinators experienced food scarcity. Honey bees lost their foraging synchronicity with blooming plants under unpredictable temperature and weather conditions. This temporal misalignment is detrimental to both plants as well as to pollinators (Memmott et al., 2007).

Case Studies

1. In Himachal Pradesh, the apple economy plays a pivotal role in sustaining the livelihood of more than four lakh families. Now it is struggling to endure climate changes like erratic rainfall, warmer winters, and reduced snowfall that are affecting the apple cultivation and

forcing it to higher altitudes. The shifting is seen in the Kinnaur, Kullu, and Lahaul Spiti regions, due to the changing climate. A rise in average temperature of 1.5 degrees Celsius has been reported by October, rainfall reduction and an increase in CO2 concentration. All these changes lead to lower apple production in 2024 and a decrease in pollinators like bees and butterflies. The ceaseless rains during the blooming period are impacting pollination and the setting of fruits, decreasing yield by 40-50% in recent years (Himachal Headlines,2024). (https://himachalheadlines.com/opinion/change-in-climate-and-its-toll-on-apple-crop/).

2. According to a report published in Down to Earth in 2023, Himachal Pradesh and the Kashmir Valley are causing major losses to apple growers in the region. The main pollinators of important crops became victims of sudden climatic changes observed in the region. The rainfall that occurred in the middle of April caused the honeybees to die in the boxes due to a loss of floral visits that resulted in pollination deficiency and a decrease in honey yields. Similarly, in Kashmir, unexpected rainfall and temperature decreases, at the time of setting of fruits, contributed to a 20-30% loss to apple production. Climate change is causing the bees' death in the region. The two main bee species used for commercial pollination services are *Apis mellifera* and *Apis cerana*. *Apis Cerana* generally forages within a kilometer, and its temperature requirement is within the range of 16 and 21°C, along with low light. The *Apis mellifera* forages within 6 kilometres at temperatures ranging from 21-25°C. The Italian honeybees outnumbered the *Apis cerana* and caused its slow decline; furthermore, Forest clearing for horticulture and farming also caused its decline. Though the *Apis mellifera* is more temperature resistant than A. cerana, they could not withstand the temperature decline and died. The erratic temperature due to climate change in the Himalayan region affects the cultivation of apple even further in the region (Down to Earth, 2023). https://www.downtoearth.org.in/climate-change/climate-change-may-be-causing-

an-apple-crisis-in-himachal-and-kashmir-this-year-here-s-how-89491).

References

Abdala-Roberts, L., Parra-Tabla, V., & Navarro, J. (2007). Is floral longevity influenced by reproductive costs and pollination success in Cohniella ascendens (Orchidaceae)?. *Annals of Botany*, *100*(6), 1367-1371.

Agera, S. I. N. (2011). Role of beekeeping in the conservation of forests. *Global Journal of Agricultural Sciences*, *10*(1), 27-32.

Ahmad, M., Uniyal, S.K., Batish, D. R., Rathee, S., Sharma, P., & Singh, H. P. (2021). Flower phenological events and duration pattern is influenced by temperature and elevation in Dhauladhar mountain range of the Lesser Himalaya. *Ecological Indicators*, *129*, 107902.

Ali, M. A., Abdellah, I. M., & Eletmany, M. R. (2023). Climate change impacts on honeybee spread and activity: A scientific review. *Chelonian Conservation and Biology*, *18*(2), 531-554.

Arya , M. et al.,(2019) Climate change and its impact on agriculture in Western himalaya. *Indian Journal of Ecology*, 46(2),378-384.

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology letters*, *15*(4), 365-377.

Belsky, J., & Joshi, N. K. (2020). Effects of fungicide and herbicide chemical exposure on Apis and non-Apis bees in agricultural landscape. *Frontiers in Environmental Science*, *8*, 81.

Bieńkowska, M., Panasiuk, B., Węgrzynowicz, P., & Gerula, D. (2011). The effect of different thermal conditions on drone semen quality and number of spermatozoa entering the spermatheca of queen bee. *J. Apic. Sci*, *55*(2), 161-168.

Botkin, D. B., Saxe, H., Araújo, M. B., Betts, R., Bradshaw, R. H., Cedhagen, T., ... & Stockwell, D. R. (2007). Forecasting the effects of global warming on biodiversity. *Bioscience*, *57*(3), 227-236.

Bucher, S. F., & Römermann, C. (2020). Flowering patterns change along elevational gradients and relate to life-

history strategies in 29 herbaceous species. *Alpine Botany*, *130*(1), 41-58.

Chand, D. B., Poudyal, K., & Jha, P. K. (2017). Shifts in leaf phenology of three Himalayan oak species: Role of wood water properties. *Ecoprint: An International Journal of Ecology*, 24, 29–36.

Cornelius, C., Leingärtner, A., Hoiss, B., Krauss, J., Steffan-Dewenter, I., & Menzel, A. (2013). Phenological response of grassland species to manipulative snowmelt and drought along an altitudinal gradient. *Journal of experimental botany*, *64*(1), 241-251.

Dimri, A. P., Niyogi, D., Barros, A. P., Ridley, J., Mohanty, U. C., Yasunari, T., & Sikka, D. R. (2015). Western disturbances: a review. *Reviews of Geophysics*, *53*(2), 225-246.

Down to Earth (2023)Climate change may be causing an apple crisis in Himachal and Kashmir this year; here's *how.https://www.downtoearth.org.in/climate-change/climate-change-may-be-causing-an-apple-crisis-in-himachal-and-kashmir-this-year-here-s-how-89491).*

FAO. 2007. Crops, browse and pollinators in Africa: an initial stock taking. Food and Agriculture Organization of the United Nations, Rome. https://openknowledge. fao.org/server/api/core/bitstreams/aef29999-2354-4f26-9eb3-2e5e9c4a7886/content. Accessed 02 August, 2024.

Gaira, K.S., Rawal, R.S., Rawat, B., & Bhatt, I.D. (2014). Impact of climate change on the ower-ing of *Rhododendron arboreum* in central Himalaya, India. *Current Science*, 106, 1735–1738.

Giannini, T.C., Cordeiro, G.D., dos Santo, G.C., dos Santo, J.O., de C.B. Im peratriz-Fonseca, V.L. and Saraiva, A.M. (2016). Climate change and its impact on bees. *Scientific Reports.* 7(1), 1-10.

Gilman, S. E., Urban, M. C., Tewksbury, J., Gilchrist, G. W., & Holt, R. D. (2010). A framework for community interactions under climate change. *Trends in ecology & evolution*, *25*(6), 325-331.

Goulson, D., Nicholls, E., Botías, C., & Rotheray, E. L. (2015). Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science*, *347*(6229), 1255957.

Hatina, S. and Tauz, J. (2016) Honey bees' foraging activities are directly influenced by temperature and wind speed. *Journal of Comparative Physiology*. *A 202(2),* 115-121.

Hegland, S. J., Nielsen, A., Lázaro, A., Bjerknes, A. L., & Totland, Ø. (2009). How does climate warming affect plant-pollinator interactions?. *Ecology letters*, *12*(2), 184-195.

Himachal Headlines. (2024, May 19).Change in climate and its toll on apple Crop. *https://www./himachalheadlines.com/opinion/change-in-climate-and-its-toll-on-apple-crop/).*

Hung, K. L. J., Kingston, J. M., Albrecht, M., Holway, D. A., & Kohn, J. R. (2018). The worldwide importance of honey bees as pollinators in natural habitats. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1870), 20172140.

5. forest conservation in and coastal IPCC(2023). Sixth Assessment Report-WGII: Impact, adaptation and vulnerability.

Klein, A. M., Boreux, V., Fornoff, F., Mupepele, A. C., & Pufal, G. (2018). Relevance of wild and managed bees for human well-being. *Current Opinion in Insect Science*, *26*, 82-88.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the royal society B: biological sciences*, *274*(1608), 303-313.

Koh, L. P., Dunn, R. R., Sodhi, N. S., Colwell, R. K., Proctor, H. C., & Smith, V. S. (2004). Species coextinctions and the biodiversity crisis. *science*, *305*(5690), 1632-1634.

Kulkarni, A.V. &Bahuguna, I.M.(2002). Glacierretreat in the Himalaya using Indian remote Sensing Satellite data. Current Science, 82(9), 1064-1069.

Kumar, R., Kumari, S., & Saxena, A. (2024). Role of honeybees in improving biodiversity and sustainable source of income. *Journal of Entomological Research*, *48*(suppl), 924-927.

Lalika, M. C. S., & Machangu, J. S. (2008). Analysis of Beekeeping Rotential in Income Generation and Coastal Forest Conservation in Lindi Region, Tanzania. *Asian Journal of African Studies*, (24), 85-107.

Lessard-Therrien, M., Bolmgren, K., & Davies, T. J. (2014). Predicting flowering phenology in a subarctic plant community. *Botany*, *92*(10), 749-756.

Maggini, R., Lehmann, A., Kéry, M., Schmid, H., Beniston, M., Jenni, L., & Zbinden, N. (2011). Are Swiss birds tracking climate change?: Detecting elevational shifts using response curve shapes. *Ecological Modelling*, **222**(1), 21–32.

Malo, Mousumi. "Why Honeybees Matter: The Importance of Bees in Agriculture." *Agri Cos e-Newsletter* 2.7 (2021): 72-74.

Masoodi, H. U., Rana, D., Thapliyal, M., & Singh, V. R. R. (2018). A study on phenological traits of Abies pindrow (Royle) Spach. in the different sites of Garhwal Himalayas, India. *Journal of Applied & Natural Science*, *10*(1).

Memmott, J., Craze, P. G., Waser, N. M., & Price, M. V. (2007). Global warming and the disruption of plant–pollinator interactions. *Ecology letters*, *10*(8), 710-717.

Mishra, M., Bhunia, P., Sen, R., Bhunia, R., Gulia, J., Mondal, T., ... & Kaushal, L. (2023). The Impact of Weather Change on Honey Bee Populations and Disease. *Journal of Advanced Zoology*, *44*.

Nautiyal, P., Bhaskar, R., Papnai, G., Joshi, N., & Supyal, V. (2020). Impact of climate change on apple phenology and adaptability of Anna variety (low chilling cultivar) in lower hills of Uttarakhand. *Int. J. Curr. Microbiol. App. Sci*, *9*(9), 453-460.

Negi, G., C. S., Singh, P., & Singh, S.P. (2021). Atmospheric warming-associated phenological earliness does not increase

the length of growing season in Himalayan trees. *Forest Science*, 67(6), 694–700.

Pant, G., Maraseni, T., Apan, A., & Allen, B. L. (2021). Predicted declines in suitable habitat for greater one-horned rhinoceros (Rhinoceros unicornis) under future climate and land use change scenarios. *Ecology and Evolution*, *11*(24), 18288-18304.

Parmesan, C., Duarte, C., Poloczanska, E., Richardson, A. J., & Singer, M. C. (2011). Overstretching attribution. *Nature Climate Change*, *1*(1), 2-4.

Partap, U. (2011). The pollination role of honeybees. *Honeybees of Asia*, 227-255.

Patel, V., Pauli, N., Biggs, E., Barbour, L., & Boruff, B. (2021). Why bees are critical for achieving sustainable development. *Ambio*, *50*, 49-59.

Pellerin, M., Delestrade, A., Mathieu, G., Rigault, O., & Yoccoz, N. G. (2012). Spring tree phenology in the Alps: effects of air temperature, altitude and local topography. *European Journal of Forest Research*, *131*(6), 1957-1965.

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Biesmeijer, J. C., Breeze, T. D., Dicks, L. V., ... & Vanbergen, A. J. (2016). *The assessment report on pollinators, pollination and food production: summary for policymakers*. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.

Rana, N., Manish, K., & Pandit, M. K. (2025). Effect of climate change on the flowering phenology of Rhododendron arboreum Sm. in the Western Himalaya. *Journal of Asia-Pacific Biodiversity*, *18*(1), 197-203.

Reddy, P. V. R., Verghese, A., Sridhar, V., & Rajan, V. V. (2012). Plant-pollinator interactions: a highly evolved synchrony at risk due to climate change. *Climate-resilient horticulture: adaptation and mitigation strategies*, 295-302.

Simon-Delso, N., San Martin, G., Bruneau, E., Delcourt, C., & Hautier, L. (2017). The challenges of predicting pesticide exposure of honey bees at landscape level. *Scientific Reports*, *7*(1), 3801.

Singh, N. P., S. Bantilan, M. C., Kumar, A. A., Janila, P., & R. Hassan, A. W. (2011). Climate Change Impact in Agriculture: Vulnerability and adaptation concerns of semiarid tropics in Asia. *Crop adaptation to climate change*, 107-130.

Singh, G., & Rana, A. (2025). Honeybees and colony collapse disorder: understanding key drivers and economic implications. *Proceedings of the Indian National Science Academy*, 1-17.

Smart, M., Pettis, J., Rice, N., Browning, Z., & Spivak, M. (2016). Linking measures of colony and individual honey bee health to survival among apiaries exposed to varying agricultural land use. *PloS one*, *11*(3), e0152685.

Stabentheiner, A., Kovac, H., & Brodschneider, R. (2012). Honeybee colony thermoregulation–regulatory mechanisms and contribution of individuals in dependence on age, location and thermal stress. *PLoS one*, *5*(1), e8967.

Stokstad, E. (2007). The case of the empty hives. *Science*, *316*(5827), 970-972.

Trunschke, J., & Stöcklin, J. (2017). Plasticity of flower longevity in alpine plants is increased in populations from high elevation compared to low elevation populations. *Alpine Botany*, *127*, 41-51.

Varikou, K., Kasiotis, K. M., Bempelou, E., Manea-Karga, E., Anagnostopoulos, C., Charalampous, A., Garantonakis, N., Birouraki, A., Hatjina, F., & Machera, K. (2020). A pesticide residues insight on honeybees, bumblebees and olive oil after pesticidal applications against the olive fruit fly *Bactrocera oleae* (Diptera: Tephritidae). *Insects*, **11**(12), 855.

Vercelli, M., Novelli, S., Ferrazzi, P., Lentini, G., & Ferracini, C. (2021). A qualitative analysis of beekeepers' perceptions and farm management adaptations to the impact of climate change on honey bees. *Insects*, *12*(3), 228.

Villette, V., Duncan, M., Spooner-Hart, R., & Neumann, P. (2020). Bees at risk: Declining populations pose threats to food security and ecosystems. *Science of The Total Environment*, *725*, 138177.

Walther, G. R. (2010). Community and ecosystem responses to recent climate change. *Philosophical Transactions of the*

Royal Society B: Biological Sciences, *365*(1549), 2019-2024.

Yadav, R. R., Negi, P. S., & Singh, J. (2021). Climate change and plant biodiversity in Himalaya, India. *Proceedings of the Indian National Science Academy*, *87*, 234-259.

Zawislak, J., Adamczyk, J., Johnson, D. R., Lorenz, G., Black, J., Hornsby, Q., Stewart, S. D., & Joshi, N. (2019). Comprehensive survey of area-wide agricultural pesticide use in southern United States row crops and potential impact on honey bee colonies. *Insects*, **10**(9), 280.