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Review Article

Colony collapse disorder: A peril to apiculture

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Abstract
Apiculture has become a profitable profession due to the high economic importance of honey and various beehive products. Honeybees are tiny social insects that perform a crucial function in the agricultural field and are necessary for good yields. Honeybees are the biological indicators of environmental health. Unforeseen rapid decrease in honeybee numbers characterized by the departure of honeybees from the colonies and accompanied by the total absence of any dead bees in the hive surrounding and inside it suggests a condition called Colony Collapse Disorder (CCD). Pesticides, pathogens, and other ecological stresses such as nutritional deficiency may add to bee extinction or CCD. Besides this, the exposure to low-level radiofrequency and microwave radiations from mobile phones also have profound undesirable effects on honeybees. Research has shown changes in biology and behaviour which includes some undesirable changes in the biomolecules concentration in honeybees because of radiation exposure. Extremely low-frequency electromagnetic field (ELF- EMF) also affects honeybee`s immune system and navigation activities. The radiation induces emotional disturbance and genetic disorders in brood which attributes to a decline in the breeding efficiency of bees. The present review is an attempt to compile the causes of CCD and discuss the management practices to be followed by the beekeepers to avoid the devastating loss to them and the planet Earth.

Keywords: Colony collapse disorder, Electromagnetic radiation, Honeybee, Pathogens, Pesticides

INTRODUCTION

Honey bees are one of the most precious insects in the world and are miniature that play an essential role in agriculture in global food supply maintenance (Kumar, 2018). Bees belong to the order – Hymenoptera of the class Insecta. This class is the largest of all in the phylum Arthropoda. The order covers around 100,000 different honey bees, sawflies, wasps, and ant species. Maximum species are eusocial and colonial organisms (Canciani *et al.,* 2019).

Honey bee traces its history back to the early cretaceous period and marks its true appearance as *Apis* about 40-50 million years ago during the Eocene period as per fossil records (Price and Grüter 2015). Honey bees have three primary groups based on evolutionary analysis:
a) *Apis dorsata* (*A.dorsata*) and *A. laboriosa* (giant bees),b) *A. andreniformis* and *A. florea* (dwarf bees), c) *A. mellifera* and *A. cerana* (cavity-nesting bees) (Arias and Sheppard, 2005).
Honey bees have the natural tendency to maintain the

contaminated free environment in the hive itself. These are social insects with a strong trait of a division of labour. Task allocation in honey bees is associated with temporal polytheism, in which workers gradually shift duties as they become old; young bees tend to brood in the central part of the nest, while older bees forage outside (Wild *et al*., 2021). Foraging for honey is the primary work and is allocated to the worker forager bees. Upon returning to the colony, honey bee foragers perform a unique type of dance called 'Bee dance' proposed by Karl von Frisch, who was awarded the Nobel Prize in 1973. It is a form of communication to notify colony members about the location of food supplies or a new nest. The acquisition and transfer of the information required for dance language communication are linked to separate sensory systems (Brockmann and Robinson, 2007).

Disappearance of bees

The "Great death of bees" occurred in Ireland in 950 AD and again in 992 AD (Bullamore, 1922). The Apiarists in the United States similarly experienced significant losses regularly. In 1903, 2000 colonies unexpectedly disappeared in Utah`s Cache valley during a "hard winter and cold spring" (Critchlow, 1904). When large colonies die in the spring because of the shortage of adult honey bees, it is often referred to as 'disappearing disease' and 'spring dwindling' (Oldroyd, 2007).

Colony collapse disorder

In recent years, there was a hasty decline in pollinator's diverseness, which ultimately affected the pollination of crops (Wyszkowska *et al*., 2019). In the 2006 winter, some beekeepers reported losing up to 90% of their hives. Similar, unexpected massive colonies disappearance has been recorded in various European nations, including Germany, Italy, Turkey, and Switzerland, which reported similar colony losses of more than 30% in 2007. Mirroring the global trends, the United States recorded the worst loss with thousands of bee colonies' deaths (Lu *et al*., 2020). Initially, seasonal winter loss apprehension was made by apiarists, but the severity of the loss experienced by these beekeepers was unprecedented. Moreover, the extended mortality at an extraordinarily higher rate and fluctuation in the death rate of colonies raised concern. The adult honey bees were mysteriously disappearing, which may be accredited to various factors like unrestrained exposure to insecticides, any infection, malnutrition, poor regulation of brood temperature etc. (Oldroyd, 2007; Ragsdale *et al.,* 2007).

It became a global phenomenon by the characteristic sudden vanishing of the adult honey bee from colonies in apiaries without any apparent cause. It was marked by the complete absence of all adult honey bees in a hive while abandoning immature bees, queen, and honey (Fig. 1). Later, in 2007, this incident was mentioned as CCD (Colony Collapse Disorder) or CDS (Honey bee's colony depopulation syndrome (vanEngelsdorp *et al*., 2006) . So, a colony/hive showing an abrupt decline in the number of honey bees, especially adult bees, without signs of infection or disease was called a 'dead colony's, or 'colony collapse disorder' (CCD) (Kumar, 2018).

The queen bee in a collapsing colony lay eggs normally but the remaining workers or colony members become unenthusiastic about the feed given by the beekeepers, unwilling to go for foraging which results in collapsed colonies (Johnson, 2011). Initial studies suggested, CCD is associated with pathogens like Israel acute paralysis virus (IAPV), *Varroa* mites, *Nosema ceranae* (Higes *et al*., 2009), *Varroa*-associated viruses, *N. microsporidia*, bacteria, fungus, pesticides (neonicotinoid, imidacloprid), and other ecological and environmental stressors (Alaux *et al*., 2010; De la Rúa *et al*., 2009; Johnson *et al*., 2009).

Possible causes of colony collapse disorder (CCD)

Climate, pathogens, and biological hazards like colony viruses, pests, and invasive robber bees are unfavourable environmental factors that cause bee extinction. The multifactorial complex is responsible for the decline in the pollinators population. There are complex interactions among the stresses and pressures (Le Conte *et al*., 2010; Vanbergen,2013).

Biological: Mites, parasites, and disease

The gut of the dead bees recovered in case of CCD exhibited high amounts of bacteria, viruses, and fungi (Chandler *et al*., 2001; Cox-Foster & vanEngelsdorp, 2009). Bee viruses noticed in CCD-infected bees were Deformed wing virus (DWV), Israeli Acute Paralysis Virus (IAPV), and Kashmir bee virus (KBV); other pathogen has been summarised (Table 1). In 2009, researchers in Spain discovered evidence that microsporidian infection of *Nosema ceranae* in bees can be one of the causes of CCD (Higes *et al*., 2010). Studies have demonstrated a positive correlation with the microbial load in the CCD colonies, *i.e.,* if the colony develops infection with *Nosema* then the susceptibility to other pathogens will increase and lead to devastating results (Cornman *et al*., 2012).

A group of researchers, while examining CCD-affected beehives, have identified the fungus- *Ascosphaera apis*, that causes chalkbrood (Johnson, 2011). The infection results in undermining the honey bee's immune function, resulting in immune deficits, which may be one of the reasons for bee deaths and disappearance (Hamzelou, 2007).

Big die-offs that occurred in the 1980s have been attributed to *Varroa* and tracheal mites (Bailey, 1985; Sammataro, 2006). Many honey bee parasites and viruses have dispersed unintentionally due to honey bee transport across long distances for different crop pollination. An example of this is the *Varroa* destructor mite that was primitively synonymous with the Asiatic honey bee (*A. cerana*) now, even observed in western bees (*A. mellifera*), which is utilized economically for pollinating crops and production of honey (Traynor *et al*., 2020; Wang *et al*., 2012). The mite had become a significant biological risk to the *A. mellifera* species (Broeckx *et al*., 2019). *Varroa* parasitism affects worker bees, male larvae and the queen's ability to replicate. *Varroa* mites feed on the haemolymph of the bees. If the infection is severe, it will hamper the growth of the brood by developing abnormalities like deformed wings and shortening of the abdomen (DWV). It is linked to viral infections, as *Varroa* breaks the barrier of exoskeleton between the virus and honey bee and hence accelerate the multiplication of the virus, which if left unchecked, leads to colony death in a period of 6 months to 2 years of the initial contamination (Goulson *et al*., 2015). *Varroa* accelerates the replication of the virus and simultaneously aggravates the deleterious effect of *Varroa* on bees. The genetic screening of the CCD colonies reported dominance of IAPV (Israeli acute paralysis virus), a dicistro-virus, which has been accredited to be spread by the *Varr*oa mite (Di Prisco *et al*. 2011). Combining the mite as transmitting vectors for pathogens (DWV), diseases, and the parasitic influence of the mites suggested it as a major factor in honey bee colony disappearance in Europe and North America (Highfield, 2009).

Paenibacillus larvae, a gram-positive bacterial pathogen (Djukic *et al*., 2014), are the most dangerous honey bee pathogen, causing American foulbrood (AFB), affecting the larva of honey bees (Genersch, 2010). Dead larvae are distinguished by loss of breathing, body flexibility, or developing inflammation, and their colony turns grey or brownish (Genersch *et al*., 2005; Oldroyd, 2007). So, it is not only a single bacteria or virus or any pathogen rather there are pathogen webs that contribute to Colony Collapse Disorder (Cornman *et al*., 2012). Three major predictive markers for winter colony collapse are DWV, Acute bee paralysis virus (ABPV), and IAPV (Berthoud *et al*., 2010; Dainat *et al*., 2012). Another virus identified as the Lake Sinai virus (LSV) also seems responsible and acts as a biomarker of CCD. LSV causes alterations in the gut microbiota of honeybees.

Along with these pathogens, certain immunoregulatory genes like vitellogenin, hymenoptaecin, and eater act as markers to detect the physiological changes before the colony collapse (Dainat *et al,* 2012; Wilson-Rich *et al*., 2008). The study and standardization of the biomarkers will help the beekeepers to prepare authenticated diagnostic tools. Few pathogens are listed (Table 1) which are directly or indirectly involved in causing colony collapse along with their detrimental effects.

Insecticides and pesticides are a necessary part of the agriculture system. These are the most contentious and debatable sources of bee declines. Pesticides have a high economic advantage, but these put bee health in direct contrast with industrial agriculture (Jones *et al*., 2006; Oldroyd, 2007). While, foraging on crops sprayed by pesticides to manage parasitic bugs, viruses, and wildflowers (weeds), the bees may encounter and pick up pesticides. Exposure to even lower doses of a pesticide during foraging has induced a negative impact on bees' health and other pollinators (Desneux *et al*., 2007). Neonicotinoids, one of the major insecticide families, are closely linked to bee declines (Jones *et al*., 2006; Colin *et al*., 2019). They are neurotoxins that target the CNS of insects, inducing overstimulation, coma, and death by binding to postsynaptic nicotinic acetylcholine receptors (Goulson *et al*., 2015). The changes in the learning abilities and the behaviour of honey bees affect the normal functioning of the beehive (Decourtye *et al*., 2011). Example of neonicotinoid insecticides, such as imidacloprid, has gained a lot of attention as they can have sublethal effects on individual and colony fitness. Moreover, bees have been observed to be easily poisoned by imidacloprid, its breakdown products produced by insect metabolism, and environmental deterioration (Zhang and Nieh, 2015). Furthermore, beekeepers have been using miticides to combat parasitic mites in their hives since the late 1980s (primarily *Varroa* mites). The persistence of pesticides in hive matrices has been observed to affect their survival rate and behaviour and lower their resistance to disease (Cornman *et al*., 2012; Henry *et al*., 2012). The bioaccumulation of pesticides in honey bees also affects the detoxification genes responsible for coping with environmental stress (John *et al*., 2020). The exposure to Coumaphos and Thymol remould the expression of genes coding for Cytochrome P-450 and protein kinase, which can affect resistance to insecticides (Le Goff and Hilliou, 2017; Gong and Diao, 2017). Exposure to various pesticides like neonicotinoids and thiamethoxam also adversely affects the reproductive potential of queen bees (Gajger *et al*., 2017; John *et al*., 2020). The pesticides or insecticides ultimately have baneful effects on bee health and ultimately on the bee colony.

Nutritional stress

Scarcity of food, i.e., pollen and nectar, can also cause depopulation of the colony. Moreover, the nutritional and energy dearth could be responsible for colony collapse. Some studies have shown that infection with *Nosema* results in an elevation of hunger in bees, which is satisfied by frequentforaging, but because of an energy deficit, the bees will not be able to return to the hive (Naug, 2009; Branchiccela *et al*., 2019).

Fig. 1. *Showing the symptoms of colony collapse disorder*

Sometimes the scarcity of food can be due to a lack of plants, the availability of crops of low nutritional value, or over-reliance on one crop (Ziska *et al*., 2016), and frequent migration of colonies, or overcrowding of bee colonies. All these factors add to the occurrence of CCD by weakening the immune system. The fact was supported by the studies on the measuring the nutritional stress on the colonies which were placed on *Eucalyptus grandis* plantation (Branchiccela *et al*., 2019). The pollen of *Eucalyptus* has low nutritional value (Somerville, 2001; Somerville and Nicol, 2001). Thus deficiencies due to lack of proper nutrition in bees make them prone to various infections and decrease their life span and immunity (Alaux *et al*., 2010).

Environmental: Climate

Climate change is a great threat to honey bee colonies. The abrupt changes in the climate disrupt phenomena like pollination adversely. Climates like drier summers result in less foraging of honey bees because of less availability of flowers in that season. This increases the food stress for bees. Moreover, the yield of various bee products also declined (Flores *et al*., 2019). Because of the drastic climate changes, the flowering time of plants has changed, altering the pollination process; hence, the biggest pollinators face nutritional deficiencies. The lack of food or nutrition leads to CCD, as already discussed. The changes in the climate alter the normal carbon dioxide also. Elevated levels of atmospheric carbon dioxide affect the concentration of proteins in the pollen, which is an essential component of the honey bee's diet (Ziska *et al*., 2016).

Few other factorsleading to the occurrence of CCD

Geomagnetism and CCD

Honey bees are social insects and distinguished foragers that gather food from up to 12 kilometres away from the hive. Honey bees can sense the Earth's magnetic field, with the presence of cytochromes in the brain and iron granules in their abdomens, serving for the chemical magnetoreception system. The magnetoreception mechanism based on magnetite indicates that the animals can feel the field through ferromagnetic magnetite (Fe3O4) crystals in their bodies. Honey bee memorizes olfactory signals or visual landmarks around the hive to navigate their way home (Liang *et al*., 2016). In the United States, the sudden disappearance of honey bees has been associated with geomagnetic storms, affecting the homing abilities of *Apis* and causing a condition named "Magnetoreception disorder" (Ferrari, 2014, Wyszkowska *et al*., 2019). The ability to resist or become susceptible to geomagnetic fluctuations is genetic and transmitted from generation to generation. The hypothesis of one colony being more susceptible to another one is less likely to occur in the case of CCD. This is because of the poor genetic diversification between different strains of the queen bee. The poor genetic diversity is because of the common queen source, or the queen bees are procured from a limited number of beekeepers (Ellis, 2016; Ferrari, 2014).

Poor colony management

Inappropriate management of bee colonies also contributes to CCD. Sometimes the beekeepers merge the weak colony with a healthy one without exploring the

Table 1. List of pathogens responsible for CCD

S. No.	Mites/Pathogens	Disease/ pathogenicity	Habitat/ affected life stages	References
1	*Varroa destructor* (Mite)	Varroasis or Bee parasitic mite syndrome sucks hemolymph weakens the immune system vector for transmitting viral infections.	Brood cell and Adult bee	Tantillo *et al*. (2015)
2	*Acarapis woodi* (Mite)	Acarine disease K type wing condition presence of crawler bees in hives.	Trachea of Adult bees, queen, drones, workers	vanEngelsdorp *et al*. (2009), Khezri & Moharami (2017)
3	*Paenibacillus* larvae (Bacteria)	American Foul Brood disease sealed brood with sunken and punctured caps larva degraded into ropy mass	Larvae	Genersch (2010)
4	*Melissococcus plutonius* (Bacteria)	European Foul Brood disease affected larvae dies before capping dead larvae color changes from white to pale yellow, then brown.	Young larvae	Ansari *et al*. (2017)
5	*Ascosphaerosis apis* (Fungus)	Chalk-brood disease (Ascophaerosis) mummification of affected larvae	Larvae/Brood	Stanimirovic *et al.* (2019)
6	*Nosema* sp. (Microsporadium)	Nosema disease (Nosemosis) Reduced egg laying capacity Affected bee behavior swollen and shiny abdomen	Adult bees, queen, drones	Tantillo *et al*. (2015)
7	Deformed wing virus (DWV)	Deformed wing disease shrunken wings reduced body size discoloration	Prominently Pupae but can infect all stages from eggs to adults	Fievet *et al*. (2006)
8	Kakugo virus (KV)	Brain problems Affected sensory and behavior coordination region of brain aggressive behavior	Adults specifically workers	Iqbal and Mueller (2007)
9	Sac brood virus (SBV)	Sac brood disease larvae fails to pupate deposition of ecdysial fluid for sac formation larvae changes from white to pale yellow.	Larvae and adults	Grabensteiner *et al*. (2001)
10	Black queen cell virus (BQCV)	Usually asymptomatic K-wing (wings are disjointed and are perpendicular to on another) develops yellowish sac like skin darker cell sides.	Larvae and pupae of queen, adult bees	Leat *et al*. (2000), Shutler *et al*. (2014)
11	Acute bee paralysis virus (ABPV)	Trembling inability to fly paralysis darker body	Adult bees, Pupae	Tantillo *et al*. (2015)
12	Kashmir bee virus	Extremely lethal	Adults and Larvae	de Miranda *et al*. (2010)
13	Israeli Acute paralysis virus	Paralysis inability to fly abdomen and thorax appear black in color loss of hair from thorax and abdomen	Adults	Maori *et al*. (2007), Tantillo *et al*. (2015)
14	Chronic bee paralysis virus	Trembling of wings and body, blackening of body bloated abdomen, hairless black adults	Adult bees, queen and larvae	Genersch and Aubert (2010).

actual reason behind the weakening, which leads to the destruction of both the colonies. For crop pollination, farmers or beekeepers frequently transport the colonies from one region to another, resulting in poor resistance of the colonies (Barrionuevo, 2007; Roy *et al*., 2018). When the honey bees are imported from a particular region with a specific climate and vegetation, the adjustment of the imported bees to the new area seems very difficult, contributing to CCD. A similar case has been recorded in Jordan, where 60% of the bees imported from Egypt were not able to adapt to the conditions (Haddad, 2011, Haddad *et al*., 2017). Similarly, the chemicals used to treat the bee colonies against infections have led to poor hive management.

Impact of mobile phone on honeybee colony

Over millions of years on this planet, bees and other insects have survived and developed diverse immune systems. According to research observations, stress like ELF- EMFs (power lines) has been creating artificial conditions, which are harmful to home-loving creatures like the honey bee (Wyszkowska *et al*., 2019). The long-term viability of colonies depends on how they react to environmental stresses. Honey bees are capable of sensing the negative stimulation and understand the deleterious outcome of these. Bee reacts aggressively and conveys those details further. For example, when faced with any danger (such as a predatory animal or invaders), guard bees can reach the hive, extrude their sting, raise their abdomen, and fan their wings to release warning pheromones (Shepherd *et al*.,2019).

Research suggests a close connection between demographic loss and cellular technology. As per recent research, an extremely low-frequency electromagnetic field (ELF-EMF) disrupts the neurological system functioning in honey bees, resulting in the loss of cognitive capacities and an increase in aggressiveness (Koziorowska *et al*., 2020). This ELE-EMF enters the ecological world through the establishment of mobile towers and phone radiation.

Honey bee navigational skills get hampered by the vast amounts of radiation emitted by towers and cell phones, stopping them from returning to their hives. In an experimental study conducted to observe the influence of the EMF, only queen, larvae, and colony bounded juvenile worker bees have remained in once-thriving hives. However, the worker bees in the test colonies never returned to their hives (vanEngelsdorp *et al*., 2009). Additionally, these radiations affect the immune system and cause its malfunction. The biochemical and physiological processes in the bee bodies have been confirmed to be affected by cell phone radiation (Kumar *et al*., 2013). The radiations have led to colony collapse disorder (CCD) and a decrease in hive product yield as well (Abdelaal, 2015).

The colony collapse may result from a single cell tower or several cell towers in the same area (Kumar, 2018). According to research, in a bee colony exposed to mobile phone electromagnetic radiation, EMR exhibited a rising number of bees leaving the hive. Colonies around cell phone towers have been found to be most influenced by the tower's electromagnetic radiation (Taye *et al*., 2017, 2018). A recent study revealed the impact of 5^{th} generation/ 5G cellular network on honey bees but this is still in the prefatory stage and should be studied in detail so that necessary, effective and timely measures can be taken to protect the bees and other organisms including pollinators (Korolev, 2022).

Effect of EMF on honey bee`s behaviour and sound production

Studies have shown the effect of EMF on honey bee behavior and buzzing sound frequency (Cucurachi *et al*., 2013; Zubrzak *et al.,* 2018). Mobile phones seem to be almost everywhere, with a simple point link between the handset and broadcasting towers. The release of RF-EMF (radio-frequency electromagnetic radiation) brings this pollutant in contact with the surrounding setting. The radiation harms the mating success and the honey bee`s life cycle (El Halabi *et al*., 2014; Odemer and Odemer, 2019). Studies have also discovered that EMF from mobile phones and cell towers may cause genetic disorders in a brood accompanied by a large decrease in the breeding efficiency of the bee (Cucurachi *et al*.,2013; Sharma & Kumar, 2010). After being exposed to RF-EMF for a long time, honey bee queens are less likely to hatch, and the bees die during the pupal stage (Odemer and Odemer, 2019).

Significant inhibitory effects on bee walk, mobility, grooming, social interactions, and wing movements have been reported (Migdał *et al*., 2021). The defense action of bees, like managing the threats and negative environmental conditions, have been harmed because of these behavioural changes (Shepherd *et al*., 2019). In a sound analysis, honey bees, under varied emotional disturbance (radiation frequency) produce various noises such as hissing (3000Hz), tooting (1200Hz), quacking (1000Hz), piping (600Hz), and squeaking (300Hz) (Favre, 2017).

Effect of radiations on the homing abilities of honey bees

Research has shown that mobile handsets can induce CCD (El Halabi *et al*., 2013). Honey bee waggling dance, foraging, and navigation activity are all harmed due to cell phone radiation (Harries-Jones, 2009). Studies have shown that honey bees are hesitant to reach the hive when a mobile phone is placed inside. The bee became unsettled and made a warning sound in response to the danger signal and the presence of the phone. A relatively high number of bees entering from another entry point (without a cell phone) has been noticed without any behavioural changes (Cammaerts, 2017).

EMF's impact on foraging

Recent studies showed that worker bees fail to return to colonies when their navigation behaviour gets disrupted by mobile radiation . In a study, bees exposed to different levels of ELF-EMF ranging from ground level to adjacent transmission power lines, detailed the reduced number of honey bees feeding, implying that EMF had an impact on the colony's capacity to get essential resources and reduced the learning, fighting, and feeding efficiency (Shepherd *et al*. 2018). From the study by Wyszkowska *et al*. (2019), it is evident that upon exposure of honey bees (*A. mellifera carnica* F.) to 50 Hz ELF-EMF at 1mT and 7mT, induced a negative influence on the foraging and migratory behaviour of the bees. Thus, ELF-EMF can be accounted as a biological stressor affecting their orientation and motor skills, finally reducing the capability of crop pollination (Lupi *et al*., 2021).

Impact of colony collapse disorder on the pathophysiology of honey bee's health

Studies clearly showed significant pathological changes in honey bees colonies suffering from CCD compared to the normal ones. The physio-pathological traits are easily visible even before the spread to the whole colony and hence can act as biomarkers for determining the health of bees. The most adversely disrupted system is the excretory system in the CCD bees. Certain traits are malpighian tubules iridescence, rectum distension, consistency of fecal matter, presence of rectal enteroliths, and colour of venom sac (vanEngelsdorp *et al*., 2017). The rectum of CCD bees has been observed to be incompletely filled (less than half) compared to normal healthy bees. The disruption of the excretory system in CCD colonies shows an imbalance between the water, nutritional balance, or osmoregulation (Nicolson, 2009). The possibility of producing less amount of faecal matter may be correlated with the consumption of less food, *i.e*., pollen or maybe the absence of nutritional food or unavailability of a variety of food.

Management of colony

Regular monitoring of the health of the beehive is an important part of bee management. To prevent a CCD-like situation, beekeepers must avoid frequent transportation of bee colonies and prohibit the merger of a collapsing colony with the strong one. Special care for the weak colonies, like the proper cleaning of hives. Additional plants, crops, or diverse plants should be made available to supplement the better nutritional value. Pollen is another requirement for hive health. Beehives need to be treated with chemicals like formic acid, oxalic acid, or some organic acids, accompanied by hive manipulation techniques to escape from mites (Nagaraja and Rajagopal, 2019). Integrated Pest Management (IPM) allows control of the spread of bacterial diseases like Foul Brood diseases in beehives (López-Uribe and Underwood, 2019). The negative impact of electromagnetism has been established, and beekeepers should be made well aware of the repercussions. Bee welfare needs to be established by seeking safety measures for beehives. The hives may be placed in areas where electromagnetism is weak, or they could be placed inside a Faraday cage or enclosure.

Conclusion

Honey bees have both vital ecological and economic importance in our lives. Albert Einstein had said, "If the bees disappear from the earth, man will have no more than four years to live". Bee welfare needs to be maintained by seeking safety measures for beehives. The health and vigour of the colony are badly affected by various pathogens and parasites. Despite the exhaustive research, the actual reason or factor responsible for CCD is still not clear. It is hypothesized as a synergistic effect of all the factors which result in the mass colony collapse. No single pathogen has been recorded that can consistently be associated with colony collapse. By following the proper hive management practices, beekeepers can safeguard themselves and their colonies from the factors which cause a significant loss. Mobile phone radiation also causes a dramatic reduction in honey bee colonies and possible health risks, which may significantly disrupt the system of food webs. Increasing air pollution levels alter the natural hive behaviour. Still, lots of research is needed to explore this area. New approaches, including the selection of virus-resistant bees, RNA interference, should be emphasized. Epidemiological studies need to be encouraged for necessary surveillance programs targeting a particular region.

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Conflict of interest

The authors declare that they have no conflict of interest.

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