

Review Article

Review of the Beekeeping Vigilance Methods and Perspectives

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Abstract

A collapse of bee colonies, for the first time in Morocco, of unknown origin, was announced on January 21, 2022 by the National Office for Food Safety (ONSSA). Causes were mentioned such as the unprecedented drought affecting the country and climate change as well as the use of pesticides and the appearance of new hive parasites and viruses. Colony collapse disorder (CCD) has been reported in several parts of the world, including Europe, Canada and Asia. Due to the agro-economic and ecological interest of the bee in the pollination of fruit trees and various seasonal and annual crops, the condition is considered alarming. Hence the need for an integrated control program that uses various monitoring measures and a set of mechanical, physical, biological and chemical control methods against hive pests. A census of the observation and countermeasures of Morocco and at the level of the world in the face of this problem was carried out. Viral diseases (*Dicistroviridae* in the United States) or parasites (in Spain, the fungus *Nosema cerenae*, *varroa* destructor in Canada, *Varroa*, itself vector of the virus), livestock management problems (transhumance and inbreeding) and the use of pesticides (the Gaucho, banned on sunflower since 1999 in France) remain the most studied causes. Surveillance and vigilance networks for beekeepers whose objective is to continuously inform the beekeeping sector of the general state of health of bees (mortality, theft of hives, invasions by other insects and parasites, etc.) everywhere in the world are essential. The *ApiVigi*® network is an example.

Keywords

Bee Vigilance, Colony Collapse Disorder, *ApiVigi*® Network

1. Introduction

Birds, rodents, monkeys and even people pollinate, but the most common pollinators are insects and, among them, bees. [1]

Pollinators contribute directly to food security. Nearly three-quarters of the plants that produce 90% of the world's food need this outside help. According to beekeeping experts from the Food and Agriculture Organization of the United Nations, a third of the world's food production depends on bees. [1, 2]

Bees are famous for their role in providing high quality food: honey, royal jelly and pollen, as well as other products such as beeswax, propolis and bee venom bees. They are also part of the biodiversity on which we all depend for our survival. "Sacred passages on bees in all major world religions underscore their importance to human societies over millennia," says a May 2019 report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

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Services (IPBES). [2]

In addition, beekeeping is an important source of income and provides an important means of subsistence in rural areas. [2]

According to the United Nations (UN), bees pollinate 71 of the 100 cultivated species providing 90% of the world's food consumable by man and his livestock. Given the vulnerability of the bee to pesticides, one can imagine the resulting deficits. Laws and procedures regulate the marketing of these products but do not seem to be sufficient. The fields are treated and retreated and exposure to a cocktail of pesticides significantly increases bee mortality. Moreover, the regulatory tests approving pesticides do not always make it possible to formally assess the risks; certain products that have been used for a long time pose a threat to bees. It can be said that the more phytosanitary treatments there are, the more residues of different pesticides there are and the more there are possibilities of multiple interactions between pesticides that can harm the health of bees. Sorting is done regularly, but, given the intensity of the phytosanitary fight, the side effects of pesticides remain a concern. [2]

Some insecticides, especially systemic neonicotinoids, when applied directly to the seed by seed coating prior to sowing, and when the seeds begin to germinate and grow, they spread throughout the whole plant and eventually end up in the guttation water that the bees lick for their sugars and mineral salts, then later in the pollen and nectar. Pollen, the main source of protein, harvested by bees, can contain many residues at high concentration levels, and this is not without consequences for them. [1, 2]

In Morocco, an unprecedented phenomenon which would concern 30% of hives in several regions of the kingdom, according to a survey – the results of which have not been made public – carried out by the National Office for Food Safety (ONSSA). [3]

Bees are mysteriously disappearing from their hives, causing concern among professionals and authorities. This disaster threatens a sector that produces 4,000 tons of honey and 80 million euros per year.

Moroccan beekeepers are in disarray. Since last summer, many of them have seen bees mysteriously leaving their hives for no apparent reason. [4]

In Morocco, drought threatens economic growth more than ever.

The country had 910,000 hives operated by 36,000 beekeepers recorded in 2019 compared to just fewer than 570,000 in 2009, according to official statistics.

In a press release published in January, the public body contented itself with affirming that “the results of the laboratory analyzes [...] rule out the hypothesis of a disease which would be at the origin of the phenomenon of disappearance of bees in some regions”. [5]

This “rapid disappearance of bees in a colony with a loss above the usually tolerated rate, which is around 20%”, has a name: the syndrome of disappearance of bee colonies summarizes a member of the Federation Moroccan interprofes-

sional organization of beekeepers. In some provinces, the loss amounts to 80%. [6]

A situation that particularly worries the beekeeping sector and the Ministry of Agriculture. Especially since “the syndrome is not known to professionals or scientists across the country,” said Agriculture Minister Mohammed Sadiki during a scientific symposium held in Rabat at the end of February 2022. [5]

According to a source from the Ministry of Agriculture, new investigations are underway to be able to precisely determine the cause and extent of the phenomenon in Morocco. [7, 8]

Referring to “research and studies carried out” to elucidate this mystery, the Minister cited several factors that could explain this desertion, in particular “climatic conditions, such as the increase in temperature and the lack of precipitation” as well as “the insufficiency of pastures in quantity and quality, the sanitary state of hives and the management practices of beekeeping”. Specialist in bee ecology, the researcher from the National Institute of Agronomic Research (INRA) Jean-François Odoux thus establishes a link between the collapse of bee colonies or the mortality of bees and the use of pesticides in France in the 1990s. [4-6]

A 2012 INRA study highlighted the role of *thiamethoxam* (a molecule from the neonicotinoid family) in the decline of bees, not by direct toxicity but by disrupting their orientation and their ability to find the hive. The work showed that exposure to a sublethal dose of this molecule led to the disappearance of bees two to three times higher than normal”. [5]

Twenty years later, the French National Agency for Food, Environmental and Occupational Health and Safety (ANSES) established, in a report published in 2015, that “the presence of infectious agents in within colonies, and the exposure of bees to pesticides of various origins and mechanisms of action, in all likelihood lead to the passage from a “normal” state of health to the expression of pathologies that can lead to their collapse, through a decrease in immunity or a decrease in the detoxification mechanisms of bees”. [9]

Added to this is the misuse of pesticides. “Some farmers are unaware of the dangerousness of these chemicals which threaten the immunity of bees”, says Bouchaib Samir. He completes his remarks by noting that the disappearance of bees has caused a drop in the production of honey, a product widely consumed by Moroccans. [4, 10]

It should be recalled that the Ministry of Agriculture had declared that it had released an additional 30 million dirhams, after an initial envelope of 130 million dirhams mobilized for the support program for beekeepers, for a national campaign to combat *varroasis*. The government spokesman had indicated that this campaign was to target 900,000 hives throughout the national territory. [5, 7]

This study aims to carry out an inventory and diagnosis of bee colonies and the measures taken to remedy this situation at the national and international level.

2. Methods

A census of the observation and countermeasures of Morocco and at the level of the world in the face of this problem was carried out.

3. Results and Discussion

A massive disappearance of bees' colonies has been observed in recent years with significant acuity during the past year and the current one.

This year, the scale of the disappearance of bees is such that the government has released aid to beekeepers of 130 million dirhams (more than 12 million euros). He also launched an extensive investigation into the disaster. "This desertion of hives is an unprecedented phenomenon in Morocco", notes the National Food Safety Office (ONSSA), in charge of the investigation, which attributes to climate change the "colony collapse syndrome of bees". ONSSA excludes the disease hypothesis. [4, 8]

In addition, "drought can today be amplified by the vulnerability of bees to diseases, transhumance, intensive agricultural practices, but also the country's desire to increase its honey production", analyzes the scientist, who studied the beekeeping environment in the south-west of Morocco. Honey production has jumped by 69% in 10 years, from 4.7 tons in 2009 to nearly 8 tons in 2019, with more than one billion dirhams (101 million euros) in turnover, according to the Ministry of Agriculture. For beekeeper Brahim Chatoui, "drought is a normal cycle. It is its intensity that is worrying today". [4]

The situation is considered alarming by beekeepers, bee researchers, ecologists, agronomists, economists because of the agro-economic and ecological interest of the bee in the pollination of fruit trees (almond, apple, avocado, cherry, plum...) and various seasonal and annual crops (melon, watermelon, onions, cucumbers, carrots, oilseeds...). According to some researchers, the survival of 80% of angiosperms and the production of almost 35% of human food depend directly on pollinators, where the honey bee remains the majority compared to wild agents. The most typical case is the Californian production of almonds where 75% of the American beekeeping livestock are assembled there by transhumance renewed contractually with each flowering. [7]

Research and studies carried out to elucidate the phenomenon of the collapse of bee colonies, recently detected in the Kingdom, attributed its appearance to an interaction of several factors, in particular climatic and environmental, indicated, Friday in Rabat, the Minister of Agriculture, Maritime Fisheries, Rural Development and Waters and Forests, Mohamed Sadiki who spoke at a scientific symposium on the syndrome of collapse of bee colonies, initiated by the ministry through the National Food Safety Office (ONSSA). [5]

Specifically, these factors are linked to climatic conditions such as the increase in temperature and the lack of rainfall, to

environmental conditions such as insufficient pasture in quantity and quality, to conditions linked to the health status of apiaries and the means of prevention used, as well as the conditions linked to the practices and management of beekeeping, he specified. [4, 9]

To this end, the Department of Agriculture through ONSSA has been mobilized with the involvement of the Moroccan inter-professional federation of beekeeping (FIMAP). Investigations were immediately initiated in the field to determine the extent of this phenomenon and to elucidate the factors that favored its appearance. [5, 7]

The first results showed that this phenomenon of the disappearance of bee colonies is "a new phenomenon" in the Kingdom and concerns "certain beekeepers in specific areas with effects of varying degrees". [5, 8]

Laboratory analyzes have ruled out "any presence of known disease of bees" which is the cause of the appearance of this phenomenon. [5]

Investigations and research are continuing within the framework of a multidisciplinary committee bringing together the various stakeholders, adds the minister.

In addition, an action plan to support the sector and reduce the effects of this phenomenon has been deployed and includes several actions, namely the creation of a national treatment campaign against *varroasis*, a well-known parasite which is object of regular treatment annually, and the implementation of an awareness program for beekeepers on good beekeeping practices. [4-6]

It also involves strengthening the national surveillance and monitoring system for bee deaths and disappearances, the conduct of scientific research in relation to this phenomenon, the support of affected beekeepers for the restocking of hives, the organization of transhumance for better management of routes and the establishment of a national database for the registration of beekeepers and their traceability with the contribution of several national and international researchers and experts from Australia, Belgium, United States, France, Belgium and the United Kingdom, international organizations, operators and professionals in the sector, representatives of consumer associations, as well as central and regional ministry officials. [8]

Indeed, Colony Collapse Disorder (CCD) is a strange and repetitive mortality phenomenon of honey bees reported already in 1998 in Europe, and in the United States, from the winter of 2006-2007. Other explosions of mortality, putting beekeepers under more pressure than ever, have been revealed in Asia and Egypt without being explicitly attached to the CCD. [6, 7]

The phenomenon, which appears as an interpretation without arguments, affects beekeeping in a large part of the globe. In the United States, it was first called "disappearing bee syndrome" or "*Fall-Dwindle Disease*" (disease of the fall decline of bees), before being renamed CCD. Its manifestation is characterized by hives suddenly emptied of their contents, generally at the end of winter, more rarely in the middle

of the foraging season. [8]

The terrible losses of colonies, which we continue to report, are most often, if not always, the result of a degradation of vitality caused by bad heredity. It is an insidious and sneaky defect, exacerbated by adverse climatic conditions, which a weakened constitution can no longer combat. Reduced vitality is also manifested by reduced attention to brood care and increased susceptibility to disease, both in the brood and in the adult bee. As practice has shown, the most productive species of bees can be reduced to nothing in a few generations by careless inbreeding.

Transhumance, a common beekeeping practice, has increased with the intensification of livestock farming and the production of specific honeys. A source of constraints for bees, it weakens them by making them more vulnerable to parasites and diseases, and reduces their ability to live naturally. These movements also promote the spread of diseases between apiaries.

The degradation of the natural food of bees is also a cause of their vulnerability. [4, 8]

Israeli acute paralysis virus of bees (IAPV) is strongly correlated with colony collapse syndrome. But it remains to be determined whether it is a symptom or a cause of the collapse, and whether it acts alone or in harmony with other causes to bring about the collapse. [4]

Like all syndromes, collapse has been the subject of scientific and media controversy. The apidologists studying it could only rely on a very weak bibliography. And it is only since the beginning of the 2000s that serious works having been published, thus allowing the constitution of an increasingly rich repertoire of information and factual observations. Considerable progress has been made, in particular the correct identification of the bio-aggressors involved in the phenomenon and the demonstration of various synergistic effects. The multifactorial thesis of the phenomenon and its complexity are now the subject of a consensus. [4, 8]

In the USA, in a report by the Department of Agriculture published in 2012, the mite *Varroa destructor*, long confused with *Varroa jacobsoni*, is accused of being the main parasite responsible for the collapse of bees. The same is true in Europe according to a study published in 2018. In a slightly earlier study, in 2010, the French Agency for Food, Environmental and Occupational Health Safety takes stock of the declared causes of apiary mortality in Europe: American foulbrood, *sacbrood* virus, chronic bee paralysis virus, acute bee paralysis virus, deformed wing virus, European foulbrood.

Overall, parasitic or viral diseases represent 69% of cases, livestock management problems 14% and pesticides 5%. [4, 10]

Closer to home, in Spain, the fungus *Nosema ceranae* is considered the main cause of bee mortality; In France, pesticides or synergies between pesticides are suspected, including Gaucho, which as a precaution has been banned on sunflower since 1999; In Switzerland, beekeeping professionals and researchers agree to define *Varroa* as the main agent of the crisis; In Belgium, it is estimated that *Varroa*, itself a virus

vector, weakens bees, thus making them vulnerable to viruses and bacteria; In the United States, a correlation between the collapse of bees, apparently disoriented and unable to return to their hive, and infection by a strain of IAPV virus (*Dicistroviridae*) has been noted; In Hawaii *Varroa destructor* and deformed wing virus (DWV) are compromised in colony collapse following the introduction of the parasite into the archipelago; In Egypt, a study found that swarms with a varied flora and a pesticide-free environment were not affected by collapse syndrome; In Canada *Varroa destructor* is named as the reason for the collapse where it is responsible for 85% of the winter mortality of colonies in Ontario; In Japan, in 2009, 25% of beekeepers said they were confronted with the phenomenon. [4, 5, 7, 8]

To understand a multifactorial phenomenon where many additive or synergistic phenomena are evoked, modeling is one of the relevant research avenues for synthesizing knowledge: it allows, based on isolated results, to quickly test many parameters and especially the many combinations of these parameters. Several mathematical models have tried to simulate the multiple factors that would explain the decline of the honeybee [11, 12], but if the Building block models of these models are individually well validated by experimentation [12], none of these models does not take into account simultaneously accounts for internal colony dynamics (genetics, queen quality, population), foraging behavior in a realistic environment (distance and resource quality), and internal and external stressors (climate, disease, parasites and chemical exposures)285. [13]

At European level, the BEEHAVE program, supported by the University of Exeter, the University of Warwick, the Helmholtz Environmental Research Center and the firm *Syngenta*, aims to develop a unique model to simulate the effect of stressors on virtual colonies in a configurable environment. The first results of the model, unpublished, would confirm the cumulative effect of several factors (*Varroa*, the distance from food resources and the deformed wing virus), but also a delay of several years between the introduction of the stress factor and the actual death of the colonies.

In addition, there are operational platforms for listing mass mortalities such as the solidarity chain on bee monitoring *ApiVigi*, which make it possible to collect and sort all observations from computer reports made on the apivigi.com site, for make available to everyone. [14]

4. Conclusion

We have seen that in various countries all the professionals agree that the situation is serious in terms of beekeeping. Combined, all the factors exposed, mean that each sheds some light on the treatment of collapse. Considering a single aspect as responsible for the phenomenon ultimately comes down to trying to solve an equation with n unknowns using only two or three. It's absurd. In a context of integrated beekeeping protection, it is recommended to intervene on all the above-mentioned factors, in

particular through accommodation and respect for good bee-keeping practices, but also the overall reduction in the exposure of bees to pesticides. The best practices in order to be able to properly manage a beekeeping livestock are based on an integrated pest management approach. An integrated control program uses various monitoring measures and a set of control methods, mechanical, physical, biological and chemical against hive pests. These measures aim to prevent infestation or infection of colonies and damage to material, and facilitate the conduct of monitoring and management activities to keep damage below a harmful threshold.

Abbreviations

ONSSA	National Office for Food Safety
CCD	Colony Collapse Disorder
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
UN	United Nations
INRA	National Institute of Agronomic Research
ANSES	French National Agency for Food, Environmental and Occupational Health and Safety
FIMAP	Moroccan Inter-professional Federation of Beekeeping
IAPV	Israeli Acute Paralysis Virus of Bees
USA	United State of America
DWV	Deformed Wing Virus

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Abdelmajid Soulaymani: Conceptualization, Formal Analysis, Supervision, Validation, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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