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Diseases and Pests Harmful to Honeybees (*Apis* spp.) and Their Management Tactics: A Review

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Authors' contributions

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Review Article

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ABSTRACT

Honeybees (*Apis* spp.) play a vital role in pollination and contribute significantly to global agriculture. However, the health and survival of honeybee colonies are threatened by a range of harmful insect pests and diseases. This review provides an overview of the major pests and diseases that impact honeybee colonies and explores the diverse management tactics employed to

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mitigate their effects. The primary focus is on key pests such as the Varroa mite (*Varroa destructor*), which inflicts considerable damage by parasitizing adult bees and their brood, facilitating the transmission of debilitating viruses. Management strategies for Varroa mites encompass chemical treatments, integrated pest management (IPM) approaches, and organic treatments to curtail mite populations and prevent colony collapse. Another significant threat discussed is the small hive beetle (*Aethina tumida*), a beetle species that disrupts hives by laying eggs in comb and consuming stored resources. Hive manipulation, traps, and chemical controls are among the tactics utilized to control small hive beetle populations and mitigate their impact. The review also addresses wax moths (*Galleria mellonella* and *Achroia grisella*), which target hive comb, potentially causing comb destruction and honey fermentation. Hive maintenance, freezing, and pheromone traps are outlined as effective strategies to combat wax moth infestations. Additionally, the review covers Nosema infections (*Nosema apis* and *Nosema ceranae*), and microsporidian parasites that compromise adult bee health by weakening immune systems and reducing foraging efficiency. Hive hygiene, medications, and genetic selection are explored as methods to manage Nosema infections and bolster colony resilience. To effectively manage these harmful pests and diseases, a holistic and integrated approach is recommended. Beekeepers are encouraged to remain informed about the latest research findings and implement appropriate measures, considering local conditions and sustainable beekeeping practices. By combining scientific knowledge with practical application, the resilience of honeybee colonies can be enhanced, ensuring the vital role they play in pollination and global food security.

Keywords: Global food security; honeybees; Nosema infections; Varroa mite and Wax moths.

1. INTRODUCTION

Honeybees (*Apis* spp.) are prominent pollinators that contribute significantly to the reproduction of flowering plants and the production of various crops [1]. Beyond their ecological importance, honeybees also play a pivotal role in global food security by facilitating the reproduction of numerous fruit, vegetable, and nut crops [2]. However, the health and stability of honeybee populations have been threatened by an array of harmful insect pests and diseases, causing considerable concern among beekeepers, researchers, and agricultural stakeholders [3].

In recent years, the challenges posed by these harmful factors have escalated, leading to increased colony losses and heightened attention to the intricate relationships between honeybees, their environment, and the various stressors they encounter [4]. This review delves into the realm of harmful insect pests and diseases that afflict honeybee colonies, examining the multifaceted impacts they have on bee health, colony dynamics, and pollination services. Moreover, it explores the spectrum of management tactics and strategies that have been developed and refined to mitigate the detrimental effects of these threats. As the interactions between honeybees and their environment become more complex, understanding the mechanisms by which harmful insect pests and diseases compromise bee health is of paramount importance [5]. A honey bee colony is affected by various pests such as the Varroa mite, small hive beetle, wax moths, and the Nosema parasite [6]. Each of these entities has its unique mode of infestation, transmission pathways, and impact on bee physiology and behavior. To counteract these threats, a range of management approaches have been devised, encompassing chemical interventions, biological controls, hive management techniques, and genetic selection [7]. By employing a combination of these strategies, beekeepers and researchers aim to preserve colony vigor, enhance resistance to stressors, and sustain pollination services. The subsequent sections of this review will delve into the specific characteristics of each harmful pest and disease, elucidating their effects on honeybee colonies and elucidating the management methods that have been developed to mitigate their negative consequences [8]. As the global community strives to ensure the health and well-being of honeybee populations, it is imperative to have a comprehensive understanding of the challenges they face and the innovative strategies that offer promise to overcome these challenges [9].

1.1 Major Pests of Honeybees Include

Honey bee colonies can face various pests and parasites that can impact their health and productivity. Some of the major pests of honeybees include (Table 1) & (Table 2):

Table 1. Diseases of honeybees and their casual organism

S. No.	Common name	Casual organism	Types of Pathogens	References
1	American foulbrood	*Paenibacillus larvae*	Bacteria	[13]
2	European foulbrood	*Melissococcus pluton*	Bacteria	[29,30]
3	Sacbrood	*Morator aetatulas*	Virus	[45]
4	Chalkbrood	*Ascosphaera apis*	Fungus	[64]
5	Stonebrood	*Aspergillus flavus*	Fungus	[70]
6	Nosema	*Nosema* spp.	Protozoa	[74]

Table 2. Pests (insects, birds, and mites) of honeybees

S. No.	Common name	Scientific name	References
1	Greater Wax moth	*Galleria melonella*	[87]
2	Lesser Wax moth	*Achroia grisella*	[103]
3	Death hawk moth	*Acherontia styx*	[113]
4	Wasp		[118]
	(i) Yellow bander	*Vespa cincta*	
	(ii) Hunter	*Palerus orientalis*	
5	Small Hive Beetle	*Aethina tumida*	[124]
6	Asian green bee-eater	*Merops orientalis*	[125]
7	Tracheal mite		
	(i) Endoparasitic mite	*Acarapis woodi*	[127]
	(ii) Ectoparasitic mite	*Varroa destructor*	[130]

2. AMERICAN FOULBROOD (*Paenibacillus larvae*)

American Foulbrood (AFB) is a highly contagious and deadly bacterial disease that affects honeybee larvae [10]. AFB is a notifiable disease in many countries, meaning that beekeepers are legally obligated to report outbreaks to the relevant authorities [11]. Additionally, successful AFB management often requires collaboration between beekeepers and local beekeeping inspectors or veterinarians with expertise in bee diseases. [12] It is caused by the spore-forming bacterium *Paenibacillus larvae* [13]. AFB can devastate bee colonies and is considered one of the most serious diseases that beekeepers must manage [14].

2.1 Symptoms of American Foulbrood (AFB)

AFB primarily affects honeybee larvae, typically those that are less than two days old [15]. Infected larvae turn brown and eventually become a dark, sticky mass [16][17]. The disease emits a foul odor, which is one of the diagnostic signs. The larval remains are often covered with tough, rope-like filaments formed by the bacterial spores [18].

2.2 Transmission of AFB

AFB is highly contagious and can spread within a colony through the feeding of contaminated royal jelly and worker bees [19]. Beekeeping equipment and hive components can also become contaminated, serving as a source of infection [20].

2.3 Management and Control of AFB

Early Detection: Early detection is crucial to prevent the spread of AFB. Beekeepers should regularly inspect their hives for signs of the disease, including examining brood frames and looking for discolored larvae and the characteristic foul odor [21].

Quarantine and Destruction: When AFB is detected, affected colonies and equipment should be isolated and destroyed. This includes burning the infected hive material to kill the bacterial spores [22].

Hygienic Practices: Maintaining good hygiene in the apiary is essential. This includes ensuring that beekeepers themselves do not inadvertently spread the disease between colonies by using contaminated equipment [23].

Antibiotic Treatment: In some regions and under certain circumstances, antibiotics such as oxytetracycline can be used to treat AFB [24]. However, this should only be done under the guidance of a qualified beekeeping inspector or veterinarian, as the improper use of antibiotics can lead to antibiotic resistance.

Re-queening: Replacing the queen in an infected colony can sometimes help control AFB, as it can lead to a break in the brood cycle, reducing the bacterial load in the hive [25].

Bee Breeding: Some research has focused on breeding honeybee colonies for genetic resistance to AFB. Beekeepers may explore the use of resistant bee strains to reduce the risk of infection [26].

Biosecurity: Implementing biosecurity measures, such as sterilizing equipment and ensuring that external sources of contamination are minimized, is essential to prevent AFB introduction [27].

Regulatory Compliance: Beekeepers should be aware of and follow local and national regulations regarding the management and reporting of AFB outbreaks. Many regions have specific rules to prevent the spread of the disease [28].

3. EUROPEAN FOULBROOD (*Melissococcus pluton*)

European Foulbrood (EFB) is another bacterial disease that affects honeybee larvae. It is caused by the bacterium *Melissococcus pluton* [29][30]. While not as deadly as American Foulbrood (AFB), EFB can still weaken bee colonies and reduce their productivity [31].

3.1 Symptoms of European Foulbrood (EFB)

EFB primarily affects bee larvae, particularly those that are 3-4 or 4-5 days old [32][33]. Infected larvae exhibit various symptoms, including larval death, discoloration, and a "melted" or "ropy" appearance [34].

3.2 Transmission of EFB

EFB is also contagious and can spread within a colony through direct contact between larvae and the contaminated brood cell lining. The bacterium can be transmitted through bee-to-bee contact or by the nurse bees feeding infected larvae [35].

3.3 Management and Control of EFB

Oxytetracycline hydrochloride (oxytetracycline) is one of the antibiotics commonly used to treat European foulbrood (EFB) in honey bee colonies [36]. However, its use does come with certain concerns and considerations [37].

Antibiotics like oxytetracycline are broad-spectrum and can disrupt the natural microbiome of honey bees. The bee microbiome plays a vital role in bee health, including digestion and immunity [38]. Disrupting this microbiome can have unintended consequences for the overall health and resilience of the colony. In some cases, the use of antibiotics can lead to bee mortality, particularly if not used according to recommended guidelines or if overdosed [39]. EFB and other bee diseases are more environmentally friendly and do not have the same negative impacts on bee health and hive products.

Some of these alternatives include: *Biological Controls:* Research is ongoing into the use of beneficial microorganisms (probiotics) that can help prevent or manage EFB by outcompeting the pathogenic bacteria responsible for the disease [40].

Selective breeding: Breeding honey bee colonies for increased resistance to diseases like EFB is another approach. Beekeepers are working to develop bee strains that are naturally more resistant to common diseases [41].

Good hive management practices: Practices such as maintaining strong and healthy colonies, providing proper nutrition, and reducing stressors can help bees better resist diseases [42].

Biosecurity Measures: Implementing strict biosecurity measures, including regular hive inspections and maintaining equipment hygiene, can help prevent the introduction and spread of diseases within bee colonies [43].

4. SAC BROOD (Morator aetatulas)

The Sacbrood virus (SBV), a member of the Iflaviridae family, is a viral disease that affects honey bees and is particularly devastating to the Asian honeybee *Apis cerana* [44]. A regional variant of SBV is known as the Chinese Sacbrood virus (CSBV) [45]. There is currently no efficient antiviral treatment available to manage CSBV infection in honey bees [46].

4.1 Symptoms of Sac brood

This disease is named "Sac brood" because of the characteristic appearance of infected bee larvae, which often resemble a sac or pouch [47]. Infected bee larvae appear swollen, elongated, and sac-like in shape [48]. They often take on a characteristic yellowish or whitish color. The head and thorax of the affected larvae may darken and become rubbery [49]. The larval sacs are often found protruding from the cells, and they may be partially or completely disintegrated [50]. Sacbrood disease is generally considered less severe than some other honey bee brood diseases like American foulbrood. In most cases, the disease does not lead to colony collapse. However, it can weaken the colony and reduce its productivity [51].

4.2 Transmission of Sac brood

The Sacbrood virus is primarily transmitted to bee larvae through contaminated food fed to them by nurse bees [52] [53].

4.3 Management and Control of Sac brood

Hygienic practices: Beekeepers should maintain good hygiene practices within the hive. This includes keeping the hive clean and removing infected larvae and pupae from the hive [54]. Regular inspections can help detect early signs of Sac brood infection [55] [56].

Requeening: Requeening the hive with a new queen from a reputable source can help reduce the likelihood of Sac brood infection [57] [58]. Some strains of honey bees may be more resistant to the virus [59].

Varroa mite control: Varroa mites are known vectors of several honey bee viruses, including the Sacbrood virus. Managing varroa mite populations through integrated pest management (IPM) practices can help reduce the transmission of the virus [60].

Nurse bee quality: Ensuring that nurse bees are healthy and free from Sacbrood virus is crucial, as they are responsible for feeding and caring for the developing larvae [61].

Maintaining proper nutrition: Providing honey bee colonies with adequate nutrition can help improve their overall health and resilience to diseases, including Sac brood [62].

Isolation of infected colonies: If Sac brood is detected in a colony, isolating that colony from healthy ones may prevent the spread of the disease to other hives [63].

5. CHALKBROOD (*Ascosphaera apis*)

Chalkbrood and stonebrood are two distinct fungal diseases that can affect honey bee broods, and they are caused by different fungal species [64]. *Ascosphaera apis* is the fungus that causes chalkbrood disease. When honey bee larvae are fed by nurse bees, the fungus's spores are consumed by the larvae. The larvae eventually starve to death as a result of the spores, which germinate in the honey bee's digestive tract [65].

5.1 Symptoms of Chalkbrood

Chalkbrood primarily affects honey bee larvae, transforming them into hard, chalk-like mummies [66]. Infected larvae turn from a healthy white color to a pale, chalky white or gray. These mummified larvae are often misshapen and have a hard consistency, which gives the disease its name [67]. Chalkbrood can lead to a significant reduction in emerging worker bees [68]. Severe infestations can weaken the overall colony, reducing its productivity and potentially leading to colony collapse if left unaddressed [69].

6. STONE BROOD (*Aspergillus* spp.)

Stonebrood is indeed caused by various species of the Aspergillus fungus, with Aspergillus flavus and Aspergillus fumigatus being among the commonly implicated species [70]. Stonebrood-infected bee larvae become mummified with a hard or stony appearance, and the exact impact of this disease on colony health is not as well-documented as some other honey bee diseases. However, the presence of Aspergillus spp. in honey bees can be a concern due to the production of airborne conidia (spores) [71].

6.1 Symptoms of Stone brood

Stonebrood is less commonly observed than chalkbrood in honey bee colonies. Infected bee larvae become mummified, but in this case, they do not turn into chalky masses [72]. The impact of stonebrood on honey bee colonies is not as well understood as chalkbrood [73].

7. NOSEMA (*Nosema* spp.)

Two types of microsporidian parasites, or spore-forming fungi, known as *Nosema apis* and *Nosema ceranae*, are the primary ones responsible for the Nosema disease [74]. While *N. apis* is considered to have developed from European honey bees (*Apis apis*), N. ceranae is believed to have evolved from Asian honey bees (*Apis cerana*) and has only currently commenced to harm European honey bees [75]. Compared to *N. apis*, *N. ceranae* appears to be more harmful since it affects more cells in the bees' mid-gut and kills infected bees rapidly [76].

7.1 Symptoms of Nosema

There are no distinct signs or symptoms of Nosema. Nosema infection may appear as the inability of bees to fly, excreta on combs or lighting boards, and dead or dying bees on the ground in front of the hive, however, these symptoms can also be brought on by other aberrant circumstances [77].

7.2 Transmission of Nosema

The spores of Nosema enter the body of the adult bee through the mouth and germinate in the gut. After germination, the active phase of the organism enters the midgut epithelial cells where it multiplies rapidly and new spores are formed [78].

7.3 Management of Nosema Disease

Fumagillin treatment: Historically, the antibiotic fumagillin was commonly used to treat Nosema disease. It can be effective in reducing the severity of the infection. However, there are concerns about antibiotic resistance and its impact on the environment [79].

Probiotic Supplementation: Some beekeepers use probiotic supplements containing beneficial microorganisms to support honey bee gut health and potentially reduce the impact of Nosema [80].

Hygienic practices: Ensure clean and dry hives: Proper hive maintenance can help reduce the spread of Nosema spores [81].

Avoid stressors: Minimize stress on honey bee colonies, as stressed bees may be more susceptible to Nosema infection [82].

Provide adequate nutrition: Well-nourished bees are better equipped to resist disease [83].

Bee genetics: Breeding honey bee colonies for resistance to Nosema is a long-term strategy. Some beekeepers work to select and propagate colonies with natural resistance [84].

Environmental considerations: Proper hive ventilation can help reduce moisture levels, which may inhibit Nosema development. Locate hives in areas with good sun exposure, as ultraviolet (UV) light can help kill Nosema spores on surfaces [85]. Regularly monitor your hives for signs of Nosema infection. You can perform microscopic analysis of bee faces to check for the presence of Nosema spores [86].

8. THE GREATER WAX MOTH

The greater wax moth (*Galleria mellonella*) has been identified as a significant threat to honeybee colonies and bee products in various regions of tropical and sub-tropical Asia [87]. Its impact is particularly pronounced from July to October and November to December [88]. The damage inflicted by wax moths extends to a range of items, including empty combs, rendered wax, comb foundation, and pollen collected by bees [89]. In a nocturnal habitat, the adult female wax moth infiltrates the hive under the cover of darkness, entering through openings like the hive entrance or small crevices [90]. These secluded spots allow the female to lay eggs directly onto combs or in narrow crevices, providing a shield against removal by worker bees [91]. Each female of the greater wax moth lays approximately 500 eggs throughout its life cycle. The larvae emerge from the eggs distributed in the hive and create nutrition tunnels in a honeycomb [92].

8.1 Symptoms and Consequences

The larvae of the greater wax moth consume pollen, bee brood, and honey from the border of open cells to the middle of the honeybee comb. Enormous web deposits left by burrowing larvae result in galleries and subsequently colony absconding [93].

8.2 Management Practices

Wax moth infestations pose a significant threat to both honeybee colonies and stored bee products. Effective management practices can play a crucial role in mitigating the impact of these pests. Here are some recommended strategies for both apiary and storage management to prevent wax moth infestations [94]:

8.3 Apiary Management

Weak colonies are more susceptible to wax moth infestations. To prevent this, consider uniting two or three weaker colonies to form a stronger one [95]. Wax moths often enter weak colonies to lay eggs. Reduce the size of the hive entrance to make it easier for worker bees to guard against intruders [96]. Any openings, cracks, or crevices that could serve as entry points for wax moths should be sealed off promptly. This will also deter other potential hive predators from infiltrating [97]. Regularly clean the bottom board of debris to remove any larvae or eggs that may be hiding there. Pay special attention to the joints of the bottom board, as these can provide shelter for wax moth larvae [98]. Infested combs should be exposed to direct sunlight for 15-20 minutes can help eliminate wax moth larvae and eggs [95].

8.4 Storage Management

Using a water-soluble concentrate of *Bacillus thuringiensis* Serotype 7 to protect stored combs can effectively deter wax moth infestations without affecting the quality of stored honey [99]. Stack empty combs in supers, leaving some space in the lowermost super. This arrangement helps prevent moisture buildup and provides better ventilation, reducing the likelihood of infestations [100]. Seal the stacked supers with a mixture of mud and dung to create an airtight environment. This barrier prevents wax moths from accessing the combs [101]. Fumigate empty combs with sulfur powder at a rate of 230g/m^3. Afterward, ensure proper sealing. Sulfur fumigation is an effective method for eliminating all life stages of wax moths [99]. Store empty combs at low temperatures (0 to -10°C) either permanently or for around 5 hours. Cold temperatures are lethal to wax moth stages and can help ensure the safety of stored combs [102].

9. THE LESSER WAX MOTH

The lesser wax moth (*Achroia grisella*) stands in contrast to its larger counterpart, the greater wax moth, in terms of size and appearance [103]. While its size is typically smaller, the greater wax moth can appear dwarfed due to inadequate nourishment during its larval stage. The adult lesser wax moth boasts a silver-grey hue, complemented by a distinctive yellow head [104]. Characterized by their delicate build, adult females measure approximately 13-16 mm in length, while their male counterparts reach around 10 mm [105]. A brief lifespan of about seven days characterizes the adult female, during which she can lay between 250 to 300 eggs [106]. Intrusion by the lesser wax moth typically targets weaker honeybee colonies. The larvae of this species exhibit a preference for dark comb, often favoring cells containing pollen or brood [107]. Notably, these larvae frequently occupy the bottom board amidst the accumulation of wax debris. The lesser wax moth larvae exhibit an intriguing behavior, forming small canals at the bases of brood cells [108].

9.1 Management Practices

Here are some management strategies to control the lesser wax moth:

Maintain strong colonies: Strong, healthy honey bee colonies are better equipped to defend against wax moth infestations. Ensure that your colonies have a sufficient population of worker bees and a productive queen [109].

Regular hive inspections*:* Conduct frequent hive inspections to check for signs of lesser wax moth infestations. Look for adult moths, larvae, or webbing in the hive [106].

Proper hive ventilation*:* Maintain good hive ventilation to prevent moisture buildup, as wax moths are more likely to infest hives with high humidity. Adequate ventilation helps keep the hive dry and less attractive to wax moths [110].

Hive hygiene: Keep your beehives clean and free of debris. Remove any old, damaged, or unused comb from the hive, as these are attractive to wax moths for egg-laying [111].

Freezing or heating frames: Frames with wax moth larvae or eggs can be frozen or heated to kill the pests. At high temperatures (29°C–35°C), greater and lesser wax moth eggs emerge rapidly, but at cold temperatures (18°C), they develop more slowly, taking roughly 30 days. In extreme cold (at or below 0°C for 4.5 hours) or excessive heat (at or above 46°C for 70 minutes), eggs cannot survive [112].

10. DEATH HAWK MOTH (*Acherontia styx*)

Acherontia styx, commonly known as the "Lesser Death's Head Hawkmoth," is a large and distinctive moth species found in parts of Asia, including India [113]. This moth, along with its close relative, the "Greater Death's Head Hawkmoth" (*Acherontia atropos*), has been associated with honey bee colonies and has gained some notoriety for its interactions with bees. *Acherontia styx* can affect bees in the following ways:

Mimicry of bee sounds: *Acherontia styx* has developed a unique adaptation to access honey bee hives. It can mimic the sounds made by worker bees by vibrating its flight muscles. This mimicry allows the moth to enter the hive without arousing the suspicion of guard bees [114].

Predation on bee brood: Once inside a honey bee hive, *Acherontia styx* primarily targets bee brood, including developing larvae and pupae. It consumes the bee brood as a source of food [115].

11. PEST MANAGEMENT

While the presence of *Acherontia styx* in a honey bee colony can be a concern for beekeepers, it is not typically considered a major threat compared to other pests like Varroa mites or wax moths. Beekeepers often use various management strategies to reduce the likelihood of moth infestations, such as hive inspections and the removal of excess comb. In some regions, *Acherontia styx* has natural predators, such as birds and other insects, which can help control its population in the wild [116].

12. PREDATORY WASPS

Honeybee colonies can be targeted and attacked by various species of wasps, which can pose a significant threat to the health and survival of the bee colony. Some harmful wasps that commonly attack honeybees include [117]:

Yellow jackets (Vespula spp.): Yellow jackets are social wasps that are known to be aggressive predators of honeybees. They are attracted to the sugary foods in the hive, such as honey and nectar, and can infiltrate bee colonies to capture and kill worker bees and raid honey stores [118].

Hornets (Vespa spp.): Certain hornet species, like the Asian giant hornet (*Vespa mandarinia*), are formidable predators of honeybees. They can decimate entire colonies by capturing and consuming worker bees, especially during late summer and early fall [119].

Paper wasps (Polistes spp.): Paper wasps are less aggressive toward honeybees compared to yellow jackets and hornets. However, they can be occasional predators and may take advantage of weakened bee colonies [120].

Bald-faced hornets (*Dolichovespula maculata*): These large, black and white hornets are known to attack honeybee colonies, especially during the late summer and early autumn when their own colonies are established. They feed on worker bees and honey stores [121].

13. IMPACT ON HONEYBEE COLONIES

Wasps capture and kill worker bees, reducing the population of foragers and nurse bees in the colony. Wasps can raid honey and nectar stores, depleting the colony's food reserves and leaving the bees vulnerable to starvation. Frequent wasp attacks can stress honeybee colonies and lead to a decline in their overall health and productivity [122].

13.1 Management Tactics

Reducing the size of hive entrances can make it more challenging for wasps to enter the hive and protect against intruders. Hanging wasp traps near the apiary can help capture and reduce the number of predatory wasps in the area. Some beekeepers use screens or netting to physically block wasp access to hives. Regular hive inspections can help beekeepers detect and address wasp threats early. Maintaining healthy, strong colonies can enhance the bees' ability to defend themselves against wasp attacks [123].

14. SMALL HIVE BEETLE (*Aethina tumida*)

This pest lays its eggs in beehives and feeds on honey, pollen, and brood. Infestations can result in the destruction of comb and stored food, leading to colony collapse [124].

14.1 Management Tactics

Placing traps with oil or diatomaceous earth to capture and kill adult beetles. Maintaining strong colonies, reducing empty spaces, and regularly inspecting and cleaning hives to limit beetle hiding spots [124].

15. ASIAN GREEN BEE-EATER (*Merops orientalis*)

The Asian green bee-eater (*Merops orientalis*) is indeed known for its diet of bees, but it primarily preys on a variety of flying insects, including bees, wasps, dragonflies, butterflies, and other flying insects [125]. While honey bees are part of their diet, they do not exclusively feed on honey bees. These colorful birds are skilled aerial hunters, capable of catching their prey in mid-air using their sharp bills.

16. TRACHEAL MITES

Various species of honeybees are affected by two types tracheal mites, namely endo-parasitic mite (*Acarapis woodi*) and ectoparasitic mite (*Varroa destructor*) [126].

Endoparasitic mite (Acarapis woodi): In the middle of the 1980s, South Carolina was the first place where tracheal mites, parasites of the honey bee, were found. Since then, the mite has spread to every part of the the nations, destroying numerous bee hives [127]. On the Isle of Wight in the English Channel, tracheal mites (*Acarapis woodi*) were first found in 1919 and were initially thought to be the source of the Isle of Wight disease, which resulted in significant colony losses [128]. Tracheal mites live their whole life cycle inside the tracheae (breathing tubes) of adult honey bees. They can be as small as 1.5 times the width of a human hair. In the bees' respiratory system, where the development cycle takes place, female mites deposit solitary eggs [129].

Ectoparasitic mite (Varroa destructor): The small reddish-brown Varroa mites (*Varroa destructor* and *V. jacobsoni*) are external parasites of honey bees [130]. Although Varroa mites may consume and live on adult honey bees, they mostly feed and multiply on the larvae and pupae in the developing brood, weakening honey bees and transferring a number of viral infections [131]. Heavy Varroa mite infections can accumulate over 3–4 years and result in scattered brood, crippled and crawling honey bees, decreased flying ability, shortened lifespans, and worker bees that are significantly underweight [132].

16.1 Management Tactics

Implement an integrated approach to tracheal mites' management, combining multiple strategies to reduce mite populations while minimizing the use of chemicals [133]. Regularly monitor mite levels in your bee colonies. Keep your hives clean and well-ventilated [134]. Replace old and infested comb, as Varroa mites can hide in wax and debris. Various monitoring methods are available, including alcohol washes, sugar rolls, sticky boards, and drone brood sampling [135]. If mite infestations are severe and other methods have proven ineffective, chemical treatments may be necessary [136]. At certain temperatures, the fumigant activity of menthol crystals destroys tracheal mites without causing harm to the bees. Hives are maintained at a constant temperature of 35 °C, which is an ideal temperature for pathogen proliferation and mold growth [137]. The crystals begin to evaporate at around 70°F (21^{o}C) and melt into a liquid at between 102°F (39 ^{o}C) and 105°F (40^{o}C). The best evaporation rate happens between 80° and 85°F because the vapors are heavier than air. Approved treatments include oxalic acid, formic acid, thymol, and various miticides [138].

17. CONCLUSION

Honeybees (*Apis* spp.) are crucial for global agriculture as pollinators. However, they face threats from pests and diseases. This review discusses major threats like Varroa mites and their management through chemical treatments, integrated pest management, and organic methods. It also covers the small hive beetle, managed with hive manipulation and traps. Wax moths are addressed with hive maintenance and traps. Nosema infections are discussed, with solutions like hive hygiene and genetic selection. A holistic approach, informed by research, is essential for honeybee colony resilience and global food security.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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