Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 05, Issue: 04 (JULY-AUG, 2025)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Diseases of Honey Bee

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Honey bees (*Apis mellifera*) play an essential role in global agriculture and ecosystem stability through pollination, contributing significantly to food security and biodiversity. However, the sustainability of apiculture is increasingly threatened by a wide range of diseases that affect both the brood and adult bees. Among the most devastating are bacterial infections such as American foulbrood (AFB) caused by *Paenibacillus larvae* and European foulbrood (EFB) caused by *Melissococcus pluton*, which severely compromise colony health and productivity. In addition, fungal pathogens like *Ascosphaera apis*, responsible for chalkbrood, and *Aspergillus* spp. causing stonebrood, pose serious risks to larval survival. Adult bees are not spared; they are frequently affected by microsporidian parasites (*Nosema apis*, *N. ceranae*), bacterial septicemia (*Pseudomonas aeruginosa*), and other infectious agents like *Spiroplasma* spp. and viruses including sacbrood virus (SBV), chronic bee paralysis virus (CBPV), and Kashmir bee virus (KBV). Environmental stressors, genetic disorders, pesticide exposure, and poor hive management further exacerbate colony losses, often mimicking or amplifying disease symptoms. Given the economic and ecological importance of honey bees, understanding the etiology, symptoms, transmission pathways, and management strategies of these diseases is crucial. This review synthesizes current knowledge on major bacterial, fungal, viral, protozoan, and non-infectious disorders affecting honey bee health, aiming to support better diagnostic, preventive, and therapeutic interventions for sustainable apiculture.

Bacterial diseases

(A). American foulbrood disease:

The disease is known as "American foulbrood, caused by *Paenibacillus larvae (Bacillus larvae)* that affects colonies of *Apis mellifera*. The pathogenic bacterium can lay dormant for up to and longer than 50 years, and the condition is contagious (Shimanuki and Knox, 2000).

Cause: Bacteria with a rod-like flagellum that is motile and extremely resistant to heat, desiccation, and disinfectants is the pathogen. The infection is spread to worker, drone, and queen larvae through the consumption of spores along with their food. There will initially just be a few dead older larvae or pupae visible in the colony. If corrective action is not taken, the disease will then swiftly spread to neighboring colonies in the apiary due to robbery, worker drooling, or contamination brought on by the beekeeper's hive operations. Spores frequently get into bee hives through imported honey. Commercially available honey could be extremely contaminated; as a result, great care should be taken in the vicinity of waste disposal facilities and honey processing facilities.

Symptoms:

- Irregular brood pattern with scattered empty cells.
- Sunken, darkened, and perforated cell cappings.
- Larvae lose their pearly white color, turning yellowish to dark brown.
- Infected larvae become soft, then decay into a sticky, ropy mass.
- Foul, unpleasant odor from the brood comb (sour or fishy smell).

- Dried larval remains form hard, dark brown scales that stick to the bottom of the cells.
- Colony may appear weak due to brood death and reduced population.
- Highly contagious; spores remain viable for decades (Shimanuki and Knox 2000).

The "stretch test" is a quick approach to determine whether AFB contributed to the brood's mortality. A small stick, match, or toothpick is placed into the decomposing larva's body and slowly and gently pulled out. The dead larva will attach to the tip of the stick if the illness is present, stretching for up to 2.5 cm before snapping back in an elastomeric manner. The "ropiness" symptom, which only appears in decaying brood, is a sign of American foulbrood disease (Shimanuki and Knox, 2000).

Transmission: American Foulbrood spreads when nurse bees feed spores to larvae, which then die as the bacteria multiply in their intestines. By the time the larva dies, new spores are formed and spread as house bees clean the cells. Contaminated honey, shared tools, and infected equipment even after years can transmit the disease. Beekeepers may unintentionally spread it, and swarms or migrating bees from infected colonies can also carry the spores.

Management:

- Sanitation and elimination of disease reservoirs is necessity
- Avoid robbing
- Minimize comb swapping between hives.
- Replace three combs in the brood chamber every year with foundation or drawn combs from honey supers.
- Burn all frames and euthanize bees.
- Scorch or fumigate empty brood boxes, bottom boards, inner covers, and lids.
- Ethylene oxide (ETO) combined with a drug treatment has been found to effectively control AFB.

(B). European foul brood disease

European foulbrood (EFB), caused by the bacterium *Melissococcus pluton* (formerly *Streptococcus pluton*), was first reported in *Apis mellifera* in the UK in 1885 and in India (Maharashtra) in 1970. It affects larvae of all castes and can also infect *A. cerana*. The disease is now found on all continents where *A. mellifera* is kept. *Streptococcus pluton* was reclassified into the new genus *Melissococcus* by Bailey and Collins (1982a, b). *M. pluton* is a short, non-spore-forming, lancet-shaped bacterium typically seen early in infection, before other microbes appear.

Symptoms: European foulbrood (EFB) affects younger larvae than AFB, typically killing them at the coiled stage (4–5 days old). Infected larvae change from white to yellow to brown and emit a foul odour. Unlike AFB, EFB scales are soft, stretchy, not stuck to cell walls, and easy to remove. Most larvae die before cell capping and often appear dislocated. A scattered brood pattern indicates severe infection, though common in brood diseases. EFB spreads similarly to AFB.

Means of prevention: EFB is largely a disease caused by stress. Thus, maintaining a strong, healthy colony is the best prevention of the disease.

Management:

To manage EFB, first confirm infestation and distinguish it from other brood diseases. In mild cases, reduce the brood nest, replace infected combs with foundation, and maintain a strong colony. In severe cases, treat with oxytetracycline (Terramycin) or another approved antibiotic as per label instructions. Always quarantine affected hives and monitor closely for any re-emergence.

Fungal Diseases

(A). Chalk brood disease (Ascosphaerosis):

The fungus *Ascosphaera apis* causes chalkbrood disease. Infection by spores of the fungus is usually observed in larvae that is three to four days old. The spores are absorbed via either food or the body surface. They cause mummification of the diseased larvae.

Symptoms: In chalkbrood disease, whitish fungal mycelia initially cover dead larvae, which swell to fill the cell, then mummify, harden, shrink, and appear chalky. As the fungus progresses, larval color changes from white to grey to black with fruiting body development (Spiltoir, 1955). Severely infested colonies show large portions of dried, sealed brood. Mummified larvae may rattle when combs are disturbed and can be found on bottom boards or near hive entrances. In some cases, they can be dislodged by tapping the comb against a hard surface (Sarwar, 2016).

Management: Like other brood diseases, white mummies in chalkbrood are often removed by hygienic bees, but this also spreads *Ascosphaera apis* spores within the colony. If not removed quickly, the fungus continues growing and spores may enter brood cells via air movement. Promoting hygienic behavior is usually effective for control. Beekeepers should ensure strong worker populations, maintain dry, well-ventilated hives, and at early infection stages, add young workers and hatching brood with sugar syrup feeding. Requeening may also help.

(B). Stonebrood:

Stonebrood, a larval disease caused mainly by *Aspergillus flavus, A. fumigatus*, and *A. niger*, is initially hard to diagnose. Infected larvae develop a whitish-yellow collar-like ring on the head, later harden into "stone-like" forms with fungal growth replacing the integument. Fungal spores vary by species: green (*A. fumigatus*), black (*A. niger*), and yellow-green (*A. flavus*), sometimes filling entire comb cells (Gilliam and Vandenberg, 1997).

Nosema

Nosema disease, caused by Nosema apis or N. ceranae (Microsporidia), affects adult bees workers, queens, and drones especially during cold, misty, or rainy weather. It is one of the most harmful diseases in adult bees, leading to high mortality as infected workers become unable to fly, crawl near hive entrances, or stand shakily on frames. The disease shortens bee lifespan and shrinks hypopharyngeal glands, rapidly weakening colony strength (Galajda et al., 2021).

Cause

Nosema disease is caused by *Nosema apis* or *N. ceranae*, Microsporidia whose spores (about 5 µm) are ingested with food and germinate in the bee's midgut. They invade gut wall cells, multiply, and produce new spores, impairing nutrition and protein metabolism**.**

Symptoms

There are no reliable field signs, but in severe cases, infected workers may show swollen, shiny abdomens. Affected bees often crawl near hive entrances or stand shakily, with reduced lifespan and shriveled hypopharyngeal glands, leading to rapid colony decline.

Transmission

Spread occurs via contaminated tools, infected queens, attendant bees, robbing, and shared food/water. After gut cell invasion, spores are excreted in feces and contaminate the hive. Spores survive for months in dried feces but die quickly in sunlight or with heat and fumigants.

Management

Keep colonies strong with good ventilation, protection from weather, and humidity control. Allow bees to defecate freely to limit spore spread. Use healthy queens and colonies, disinfect equipment (preferably with heat/fumigation), replace combs every two years, and treat with Fumagillin (Fumidil-B) if needed.

Septicemia

Pseudomonas aeruginosa, also known as Pseudomonas apiseptica, causes septicemia in adult honeybees by destroying connective tissues of the thorax, legs, wings, and antennae. Infected bees fall apart when handled and emit a putrid odor. This gram-negative bacterium appears singly, in pairs, or short chains. Death occurs within 24 hours, and the characteristic odor and disintegration appear by 48 hours (Church et al., 2016).

Spiroplasmosis

Spiroplasmosis is caused by *Spiroplasma* species, which are helical, motile, cell-wall-free bacteria found in the hemolymph of infected adult bees.

Protozoan Diseases

Protozoa are mostly single-celled organisms and are not commonly associated with honeybee brood diseases.

Amoeba Disease:

Amoeba disease is caused by *Malpighamoeba mellificae*, which infects adult bees' Malpighian tubules. After ingestion, cysts develop into trophozoites that damage tubule epithelium, disrupting excretion and hemolymph balance, and may predispose bees to *Nosema* infections (Schafer et al., 2022).

Viral Diseases

(A). Sacbrood:

Sacbrood is the only common brood disease in honeybees caused by a virus. Infected pearly-white larvae turn grey, then black, and die just before pupation while in an upright position. Their heads may tilt toward the cell center and appear darker. When removed, affected larvae look like water-filled sacs, and later dry into fragile black scales.

Symptoms: Dead brood cells appear scattered among healthy ones. Adult bees may pierce or remove blackened cappings. Larvae darken, their head tips upward like a canoe end, their skin toughens, and contents become watery, forming a sac-like appearance (Grabensteiner et al., 2001). The larva then dries into a hardened, nearly black scale.

Transmission: Nurse bees transmit the virus to larvae through brood food. After larval death, house bees cleaning the cells spread the virus further. Typically, only one or a few colonies are affected in an apiary.

Management: Stress triggers sacbrood, so strong colony maintenance is key. Colonies usually recover naturally, but severe cases may require requeening or relocation.

(B). Chronic Bee Paralysis:

Mature bees affected by chronic bee paralysis are usually found on the top comb bars. These bees are flightless and exhibit intense shaking. In severe cases, large numbers of bees crawl out of the hive entrance. They often appear glossy, hairless, and black. Occasionally, toxic substances can cause similar paralysis-like symptoms (Budge et al., 2020).

(C). Filamentous Virus:

Also known as F-virus or bee rickettsiosis (Hou, 2017), this disease can be diagnosed using dark-field or phase-contrast microscopy to examine the hemolymph of infected adult bees. The hemolymph appears milky white and contains numerous spherical to rod-shaped virus particles.

(D). Acute Paralysis Bee Virus and Kashmir Bee Virus:

Kashmir bee virus (KBV) and acute paralysis bee virus (APBV) are serologically related; thus, antiserum from one reacts with the other (Hung et al., 1996). These viruses often infect healthy-looking adult bees. While APBV affects only adults, KBV causes mortality in both adults and brood, though neither virus produces distinct visible symptoms.

(E). Thai sac brood virus (TSBV):

TSBV specifically affects *Apis cerana*, with the dead brood observed during the pre-pupal stage. Pupae form sac-like bodies with lemon-colored fluid at the rear, and larvae turn from yellow to brown to black in advanced stages, without any foul smell. The virus caused major losses in Indian bee colonies in the late 1990s, significantly impacting the beekeeping industry (Rao et al., 2016).

Management:

Prevention is better than cure. Infected colonies should be isolated, dequeened for a few days, and then requeened using a healthy queen. Do not reuse combs from infected hives. There is no effective medication for sac-brood; however, colonies often recover on their own due to hygienic behavior, especially if the disease is already prevalent in the area. In severe cases,

beekeepers should requeen, remove infected brood combs, and support the colony with food and worker bees. Stress conditions like food shortage, damp or cold weather, poor hive hygiene, weak queen, or co-existing diseases often trigger the outbreak.

Table 1. Comparative Symptoms of Brood Diseases

Symptom of dead brood	American Foulbrood	European Foulbrood	Chalkbrood	Sacbrood
Appearance of comb	Sealed brood – discoloured and sunken, punctured cappings	Sealed brood has sunken, discoloured, and frequently perforated cappings.	Mummies found in sealed and unsealed brood	Scattered sealed brood with punctured cappings
Age	Generally older sealed larvae and young pupae	Mostly immature, open larvae; sometimes older, coiled larvae	Older larvae in upright cells	Usually older sealed larvae upright in cells
Color	Dull white to light brown, coffee brown, dark brown, and finally nearly black	dull white, coffee brown, light brown, dark brown, and eventually nearly black	Chalk white or black	Grayish or straw-colored, becoming brown or darker
Consistency	soft to sticky to ropy	Watery and granular; occasionally ropy or sticky	Hard and rocklike	Watery and granular; tough skin forms a sac
Odor	Odour, from mild to pungent	From a mild sour to a penetrating sour	Slight, non-objectionable	None to slightly sour
Scale characteristics	Black, brittle, hard; flattens on cell base; strongly adheres; tongue may be visible	Twisted in cell; not adherent; black and rubbery	Not adherent; chalky and brittle; white to black	Canoe-shaped; not adherent

Noninfectious Disorders

Honeybee colonies may suffer from noninfectious conditions like starvation, overheating, chilling, poisonous plants, and environmental stress, which can be as damaging as diseases. Poor hive management is a key factor, and such disorders often stem from neglect, lethal genes, toxic plants, or chemicals. These conditions typically result in dead or discolored pupae and can be prevented with best practices.

Neglected Brood:

Worker bees manage hive tasks through division of labor, with nurse bees caring for the brood. A sudden drop in adult bee population can cause larvae and pupae to die due to abiotic factors like chilling or starvation (Calderone and Tucker, 1997).

Chilled brood:

Chilling usually occurs in early spring when brood nests expand faster than adult bee populations can protect. Sudden cold snaps cause brood on the edges to chill, turning them yellowish with black edges or brownish-black and watery. In severe cases, bees may uncap cells and decapitate pupae. Wax moth larvae can also cause similar decapitation (Calderone and Tucker, 1997).

Starved brood:
During food shortages, brood may be eaten or expelled, and larvae starve due to a lack of nurse bees. Starved larvae may crawl out in search of food. Emerging bees may die with heads out and tongues extended. Dead bees may be found head-first in cells. Regular checks for honey supply are essential (Calderone and Tucker, 1997).

Spotty Brood:
Spotty brood may signal AFB, EFB, Varroa mites, queen failure, or inbreeding. A healthy queen produces uniform brood, but a failing queen lays irregularly, causing mixed cell stages. Patchy brood may also include worker and drone brood. Illness should be checked, and re-queening may be necessary (Calderone and Tucker, 1997).

Overheating:
When worker bees are suddenly lost during hot weather, the brood overheats. Pupae appear dark and oily; overheated larvae turn brownish or black and become fluid. Newly emerged adults may be wingless. Brood cell cappings may look melted, discolored, sunken, or pierced. Inadequate ventilation or water during heat can cause overheating, making dying bees crawl while flapping their wings, with hazy, moist wings. A large number of dead bees may be seen at the hive entrance.

Genetic Lethality:
Honey bees may die from genetic defects during development without known disease symptoms. Drone brood from laying workers or drone-laying queens sometimes dies with signs resembling EFB. The assumed cause is genetic lethality, not infection.

Plant Poisoning:
Toxic plants may harm bees in certain areas, especially during flowering if nectar is toxic. If the toxin is in pollen, symptoms may persist as long as pollen remains in the comb. Unlike pesticide poisoning, plant poisoning occurs gradually and regularly in the same place. Ericaceae family plants (e.g., Rhododendron, Agarista, Kalmia) contain grayanotoxins, which cause dizziness, hypotension, and heart block by disrupting sodium ion channels (Yan et al., 2022).

Purple brood:
Purple brood results from bees consuming pollen and nectar from *Cyrilla racemiflora* (summer titi). Infected larvae turn blue or purple. Beekeepers can respond by:
(1) relocating colonies away from such plants during bloom, or
(2) feeding sugar syrup to dilute harmful effects.

Paralysis:
Aesculus californica (California buckeye) is one of the most toxic plants in the US, causing symptoms in field bees similar to chronic bee paralysis, such as trembling and turning black due to hair loss. Eggs often fail to hatch, or larvae die shortly after. Pollens from milkweed (Asclepias spp.) form paired coherent grains called pollinia connected by a thin filament. When detached, the pollinia resemble a wishbone. Bees often get trapped in this structure and either can't escape or return to the hive encumbered, crawling with pollinia still attached (Stone, 2012).

Pesticide Poisoning:
Sudden death of adult bees is a major indicator of acute chemical exposure. Numerous dead or dying adult bees and sometimes pupae are found near hive entrances. Foragers often die away from the colony or bring contaminated pollen or honey back, poisoning nurse bees and causing brood neglect. Symptoms vary depending on the pesticide, with systemic insecticides like neonicotinoids and phenypyroles weakening immunity and causing lethal or sublethal effects (Hassani et al., 2005).

Management of honeybee poisoning
The basic principle in the management of bee poisoning is to avoid the exposure of honey bees to toxic effects. To manage poisoning, both beekeepers and farmers must minimize honeybee exposure to toxic substances. Beekeepers should (1) maintain colonies where pesticide use/drift is minimal,

(2) coordinate with farmers to prevent misuse, and
(3) feed sugar syrup during pesticide applications to discourage foraging.

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