The Journal of Agricultural Sciences - Sri Lanka
Vol. 21 No 1, January 2026. pp 261-269
https://doi.org/10.4038/jas.v21i1.11306

REVIEW

Varroosis – the Scourge of Today's Apiculture, Aetiology, Life Cycle and Pathogenesis

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Received: 11th November 2024 / Accepted: 21st October 2025

ABSTRACT

Purpose: *Varroosis caused by the mite Varroa destructor is considered as the most damaging parasitic disease on honeybees (Apis mellifera). Since its initial jump to Apis mellifera colonies, the mite has spread to all continents where beekeeping is practiced. Nowadays, Varroosis causes high colony losses around the world; it also weakens honeybee colonies making them susceptible to other diseases. However, in order to be able to fight Varoosis we need to know well its aetilogical agent, Varroa destructor. Thus the purpose of this review is to focus on Varroa destructor, its life cycle and pathogenesis.*

Research Method: *The information for this review was obtained by searching available online scientific databases (Web of Science, Scopus, Google Scholar, CABI). Some research articles and beekeeper's journals unavailable in electronic databases, but available in paper form were also used as a source of information. After that, the information was analyzed, summarized and written in a reader-friendly form.*

Findings and Values: *From the present review, the reader will obtain comprehensive knowledge of the main characteristics (spread, morphology, biology and behavior) of Varroa destructor, the causative agent of Varroosis. The reader also will become acquainted with the pathological changes caused by the mite and its complex interactions with other aetiological agents.*

Keywords: *Life cycle, Pathogenesis, Varroosis, Varroa destructor.*

INTRODUCTION

Varroosis is a parasitic disease which affects bee brood and adult honeybees. Varroosis is one of the diseases which cause the most losses of honeybee colonies worldwide and is nowadays considered as one of the major problems for world apiculture (Boecking & Spivak 1999, Guzmán-Novoa *et al.* 2010, Rosenkranz *et al.* 2010, Martin *et al.* 2012, Smith *et al.* 2013, Hristov 2014, Traynor *et al.* 2016, Brodschneider *et al.* 2018, Steinhauer *et al.* 2018). Varroosis is also the most prevalent disease on honeybees around the world – it is present in all places where honeybees are kept with a few exceptions of some isolated islands. Until recently, Australia was the only continent free from Varroosis, but in 2022 the causative agent *Varroa destructor* was detected in the country and has spread rapidly.

In Bulgaria *Varroa destructor* was introduced around 1970 from the former USSR (Griffiths & Bowman 1981); Varroosis was registered as a disease in 1971. One of the first scientists who reported the spread of Varroosis in Bulgaria was Parvulov (1974, 1975). Today in Bulgaria the causative agent is spread all over the country and

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Varroosis causes significant annual damage to Bulgarian beekeeping (Hristov 2014). Without taking annual prophylactic measures against Varroosis, the honeybee colonies collapse; the disease can destroy all honeybee colonies in the apiary and under certain conditions in the whole region. For these reasons Varroosis is included in the list of notifiable honeybee diseases by the World Organisation for Animal Health (OIE 2024).

AETIOLOGY AND LIFE CYCLE

The causative agent of Varroosis is the mite *Varroa destructor*. Initially, the species was described under the name *Varroa jacobsoni* in 1904 (Oudemans 1904a, Oudemans 1904b) as a species parasitizing on wild Indian bee (*Apis cerana*) in Java island, Indonesia. However, during the 50s of the 20-th century the mite changed its host, began parasitizing on honeybee colonies (*Apis mellifera*) (Oldroyd 1999, Roberts *et al.* 2015) and spread worldwide just for a few decades. In 2000 the species name was changed to *Varroa destructor* after Anderson and Trueman (2000) discovered species differences between the mites parasitizing on honeybees and the mite *Varroa jacobsoni*, so it became clear that mites described under the name *Varroa jacobsoni* are more than one species. Nowadays, many haplotypes of *Varroa destructor* are known, but only two of them have changed their hosts from *Apis cerana* to *Apis mellifera*. These are: Korean haplotype (K1), which is distributed globally and is considered highly virulent, and Japanese haplotype (J1) distributed in Japan, Thailand, North and South America, which is considered less virulent (De Guzman *et al.* 1998, Anderson & Trueman 2000). Meanwhile, the closely related mite *Varroa jacobsoni* also has taken an independent jump from *Apis cerana* to *Apis mellifera* in Papua New Guinea (Roberts *et al.* 2015), but at the moment its ability to spread outside of this region is unknown.

The body of *Varroa destructor* mites has two clearly distinguishable parts: idiosoma (dorsal and ventral shields) and gnathostoma (mouth parts) (Rosenkranz *et al.* 2010). The mite *Varroa destructor* has two sexes; females are bigger than males and can be seen with the naked eye. Female mites are red-brown in color (De Jong *et al.* 1982a) and have an ellipsoidal, flattened body which is 1.1 mm long and 1.6 mm wide (Rosenkranz *et al.* 2010). The body measurements can vary in different *Varroa* populations (Maggi *et al.* 2012). The mites have four pairs of short, segmented legs which protrude from the front end of the ellipsoidal shield (Coffey & Mary 2007). The whole body of the mites including the legs and mouth organs is covered by hair (MAAREC 2004). The mites are highly mobile and their legs supplied with suckers (De Ruijter & Kaas 1983) as well as the flat form of their body facilitate mite attachment to the bees. Male mites are pale-yellow in color with elongated bodies (De Jong *et al.* 1982a) and longer legs than females (Ifantidis 1983, Huang 2012). Males are significantly smaller than females with 0.7 mm length and 0.715 mm width (De Jong *et al.* 1982a). Female mites attach themselves to the bodies of adult bees most often between bee's abdominal segments and hold there due to their body shape and hair (Sanford *et al.* 1998).

Life cycle of *Varroa destructor* consists of two stages: reproductive stage and dispersal stage (previously called phoretic stage) (Ramsey *et al.* 2019, Traynor *et al.* 2020). The reproductive stage takes place in the sealed cells with worker or drone brood where females raise their offspring; during the dispersal stage female mites travel on the bee's body while feeding from the host's tissues. The reproductive stage begins when a female mite enters an unsealed brood cell 15–20 hours prior to sealing (Boot *et al.* 1993). Today we know that *Varroa destructor* uses kairomones as a form of chemical "espionage" to select brood cells containing bee larvae at appropriate age (Nazzi & Le Conte 2016). Drone brood is preferred 8 times more than worker brood due to more favorable conditions for reproduction (Fuchs 1992). One brood cell is usually infested by one female mite; however, it is possible for more than one mite to enter one brood cell (mainly when the colony has a high level of infestation), in which case offspring from different mothers mate between each other (Beaurepaire *et al.* 2019).

After entering the cell, the female mite hides on the bottom of the cell in larval food and breathes through its snorkel-like peritrema which protrudes above the liquid level (Rosenkranz *et al.* 2010). After sealing the cell, the female exits larval food, gets on the bee larva and pierces a relatively big hole (100 µm) in the larva's cuticle to create a feeding site for itself and its offspring (Kanbar & Engels 2003, De Lillo *et al.* 2016, Li *et al.* 2019). That wound remains open because of anticoagulants in the mite's saliva and suppression of healing (Richards *et al.* 2011, Becchimanzi *et al.* 2020, Traynor *et al.* 2020). Oogenesis begins a few hours after the cell is entered (Steiner *et al.* 1994, Garrido *et al.* 2000, Rosenkranz & Garrido 2004). About 60–70 hours after sealing, the female lays its first egg (Martin 1994, Rosenkranz *et al.* 2010). This egg is unfertilized and develops into a haploid male (Ifantidis 1983, Häußermann *et al.* 2020). After that, approximately every 30 hours the mother lays a fertilized diploid egg which becomes a new female (Rehm & Ritter 1989, Martin 1994).

Newly hatched mites develop through two nymphal stages (proto and deutonymph) before turning into adults (Boecking & Genersch 2008). After becoming adults (on the 9th-10th day after cell sealing for the first female), the male mates with his sisters in the cell (Rehm & Ritter 1989, Donzé *et al.* 1996). The reproductive stage ends when the mother and her adult daughters exit the cell with the emerging bee. The male and undeveloped females are left to die in the empty cell (Roth *et al.* 2020).

During mating each female receives 30–40 spermatophores which she stores in her spermatheca and uses for life; mated females do not mate again (Huang 2012, Häußermann *et al.* 2016). One female can lay a maximum of 6 eggs in worker brood and 7 in drone brood per reproductive cycle (Ifantidis 1983). Under field conditions one female has 1.5–3 reproductive cycles in her lifespan (Rosenkranz *et al.* 2010).

The next stage in *Varroa destructor* life cycle was renamed from phoretic stage to dispersal stage because the mites not only use bees as transport but also feed on them (Ramsey *et al.* 2019). The dispersal stage begins when the newly hatched bee exits the cell carrying the mother and adult daughters. The daughters quickly switch to nurse bees (Kuenen & Calderone 1997, Xie *et al.* 2016) to activate their ovaries and feed. Nurse bees also provide access to brood cells (Xie *et al.* 2016). Preferences of mites to bees performing different tasks depend on season and infestation level: at high infestation levels, mites are more common on foragers (DeGrandi-Hoffman *et al.* 2016). Mites are usually found on the third abdominal segment and prefer the left side of bee's body (Ramsey *et al.* 2019). Mites freely crawling on combs are rare (Kuenen & Calderone 1997). During wintering, the dispersal stage lasts several months (Boecking & Genersch 2008). Total life longevity of female mites is 2-3 months during the summer and 6-8 months during the winter. For now, it is not clear how many times one female mite can change its location from one bee to another; the duration of mite's stay on one bee is also not known.

PATHOGENESIS

The deleterious effects on bee brood, bees and bee colony are caused mainly by female mites of *Varroa destructor* since the males of the species are short-lived in the sealed brood cells (Bruyn 1997). The damage caused by Varroosis are due to the fact that female varroa mites in *Apis mellifera* colonies parasitize in drone brood as well in worker brood while in their original host *Apis cerana* the mites parasitize in drone brood only (Peng *et al.* 1987). Besides brood, *Varroa destructor* parasitizes also on drones and worker bees (Rosenkranz *et al.* 2010).

On individual level, the frequent feeding of mites from the bee larva through their piercing-sucking organs causes formation of a constant wound on the body of the larva through which bacterial infections enter the larva (Kanbar & Engels 2003). For decades it was considered that mite *Varroa destructor* feeds itself by direct intake of hemolymph from bees and larvae. However, the new research of Ramsey *et al.* (2019) proved that the mite feeds mainly from the cells of fat body of bees and larvae. At that, the cells of fat body are digested beforehand (extraoral digestion) from the enzymes in mite's saliva (Ramsey *et al.* 2018). Feeding from the fat body leads to lower concentration of hemocytes as well as lower expression of the enzyme phenol oxidase (Koleoglu *et al.* 2018) and affects adversely immune system of bees and larvae (Shen *et al.* 2005). Parasitizing of *Varroa destructor* on bee larvae leads to smaller body size and lower weight of newly emerging bees (De Jong *et al.* 1982b, Gechev 1995, Duay *et al.* 2003, Rosenkranz *et al.* 2010, Van Dooremalen *et al.* 2013). Worker honeybees which are parasitized by *Varroa destructor* have smaller hypopharyngeal glands and when they are parasitized by 2-3 and more mites, they also have smaller mandibular glands (Ayoub *et al.* 2015). In addition, high infestations with mites lower the learning capabilities of bees; heavily infested forager bees are disoriented on their way back to the hive (Kralj & Fuchs 2006). Infested drones weigh less and have lighter testicles (Omar 2017) and consequently have impaired spermatogenesis and reduced flight capabilities (Lewbart 2012). In conclusion, the infested bees have reduced lifespan and reduced working capacity which in turn affects negatively the whole bee colony. It is known that when high infestations with *Varroa destructor* are present big proportions of worker honeybees in the colony are inactive (Annoscia *et al.* 2015).

Lots of reports provide evidence that *Varroa destructor* acts as mechanical and/or biological vector for transmitting a wide range of viruses and bacteria (Parvanov 1992, Ritter 2004, Kevan *et al.* 2006, Francis *et al.* 2013, Mondet *et al.* 2014, Tantillo *et al.* 2015, Emsen *et al.* 2015) which in turn worsen Varroosis and reduce viability of the whole bee colony (Boecking & Genersch 2008). Up to now 18 bee viruses are isolated; the most frequently identified viruses in Varroa infested honeybee colonies are: deforming wing virus (DWV), acute bee paralysis virus (ABPV), Israeli acute bee paralysis virus (IAPV), Kashmir bee virus (KBV), sac brood virus (SBV), black queen cell virus (BQCV) and chronic bee paralysis virus (CBPV) (Ball 1983, Ball & Allen 1988, Chen *et al.* 2004, Yue & Genersch 2005, Chen & Siede 2007, Boecking & Genersch 2008). The direct role of *Varroa destructor* as a vector for transmitting viruses is proved only for deforming wing virus and acute bee paralysis virus (de Miranda *et al.* 2010, Martin & Brettell 2019). At that, deforming wing virus is the most frequent (Tentcheva *et al.* 2004). Since this virus co-evolved along with *Apis mellifera* before distribution of Varroosis it was found in hives in the form of asymptomatic infections (Wilfert *et al.* 2016). With distribution of Varroosis DWV has spread widely since the mite transmits the virus during its feeding from different hosts. Because of facilitated transmission of DWV more virulent variants of the virus have spread (Martin *et al.* 2012, Ryabov *et al.* 2014, Grindrod *et al.* 2021). For a long time, it was not known whether *Varroa destructor* is a mechanical or biological vector of DWV i.e., whether the virus multiplies itself in the body of the mite. Some researchers (Posada-Florez *et al.* 2019) did not find evidence that less virulent DWV variant A multiplies in the body of the mite. However, other scientists discovered that more virulent DWV variant B infects and multiplies itself in the intestinal epithelium and saliva glands of the mite (Gisder & Genersch 2021), which is evidence that *Varroa destructor* is not only mechanical, but also biological vector of the virus (Gisder *et al.* 2009, Gusachenko *et al.* 2020, Yañez *et al.* 2020). Because of the complex and not fully revealed interactions between mites, viruses and bees, today most researchers consider that in Varroosis, there are not two sides cause-consequence relationships, but a triangle of interactions (mites-viruses-bees).

CONCLUSIONS

After its initial jump on, *Apis mellifera Varroa destructor* has spread on honeybee colonies all over the world. Although the mite is known for decades, some aspects of its biology and behavior still remain elusive. The same can be said about pathological changes which mite is causing to the bee larva, adult honeybee and bee colony. Interactions of *Varroa destructor* with other aetilogical agents such as viruses also need further investigation.

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