



A review on “The management of varroa mites on honey bee colony”

Abhinash Borah, Munna Yadav, Satish Krushna Gharde

Department of Entomology, School of Agriculture, Lovely Professional University, Punjab, India

Abstract

Varroa destructor is one of the most serious threats to honey bee health globally. Beekeepers prefer to use chemical treatments to control the ecto-parasite, though the overuse and mismanagement of the treatments led to the development of resistance in *Varroa* mites. Integrated Pest Management (IPM) is a sustainable approach for the pest management that depends on a combination of control methods that minimize the harmful environmental impacts. Through this article, we provide a review of the components of IPM regarding *Varroa* control. These include identification, morphology, seasonal incidence, food and nutrition, damage to honey bees, and monitoring for *Varroa*. Further, we also provide a descriptive review of the different cultural, mechanical, biological, and chemical control methods used against *Varroa destructor* globally. To encourage the people to adopt beekeeping, a successful IPM approach, managing *Varroa* populations, must be an improvement over the conventional methods and it must be cost-effective that can be utilized readily by the beekeepers. It is our intention that we provide the most options available through review of *Varroa* control within the context of IPM. We hope that this work of ours will be of great help in protecting the honey bees from the *Varroa destructor*.

Keywords: honey bee, varroa destructor, monitoring, control (cultural, mechanical, biological, chemical)

Introduction

In recent years there is research in the field of honey bees has been tremendous. More and more people are attempting to domesticate honeybees as they receive honey and wax along with their aid in pollination. But not all the domestications are successful as honey bees too can be attacked by pests and diseases. One of their pests is the varroa mite (*Varroa destructor*) belonging to the class Arachnida. According to Anderson and Trueman 2000, Varroa mite is one of the most destructive pest of honey bee feeding ectoparasitically on the insect body the similar finding was also reported by Rosenkranz *et al.* 2010 and Dietemann *et al.* 2013. There might be some confusions regarding the name of the mite as the publications 2000 mention it as *V. jacobsoni* instead of *V. destructor*. The name was changed after Anderson and Trueman 2000 demonstrated that the invasive mite population was not the same species from Indonesia as described by Dietemann *et al.*, 2015 with the help of molecular tools. Except for Australia, and several isolated islands, *V. destructor* infestation is at near-global populations.

Varroa mites and the viruses vectored by them are viewed as the leading killer of the honeybees (Jeffrey *et al.* 2016). It's not just the mites that affect the honey bees, also the chemicals used to control them harm the bees along with the by-products. As per the studies of various researchers, bees were exposed to neonicotinoids through ingestion of contaminated pollen, nectar, guttation water, or exuded water droplets. There has been proof of the presence of a wide range of pesticides in honey bee hive resources. This may be the result of contaminated soil or dust deposited over bees, plants, or both (Chauzat *et al.* 2011; Mullin *et al.*, 2010;).

Virtually, all wild honey bee colonies have been wiped out by the Varroa destructor mites, and the beekeepers continue to struggle with varroa infestations in their bee colonies. In North Carolina alone, the invasion of Varroa mites led to the drop of bee domestication by approx. 44 percent (Ambrose *et al.* 2016). Therefore, it is of great importance to completely understand the varroa mite and the options available to control its infestations. The mite was first found in the year 1990 in North Carolina having the capability to wipe out the whole colony (Ambrose *et al.* 2016). With the help of specialized mouthparts, the mite feeds on the haemolymph of pupae and the adults that can lead to premature mortality. The impact of the mites can be profound and intense. The synchronization of mite brood development and bee colonies development was observed closely. the colonies with high Varroa mite infestation may produce little or even no honey (Ritter, 1981)^[43].

The identification of the species is important to protect the bee colonies by taking adequate steps in control. Misguided information can lead to waste of resources, time and labour and can have potential to harm the ecosystem. Varroa destructor is a pest of great importance in honey bee's life. Through this review work, I tried to understand the the biology of Varroa mite: its morphology, life cycle, reproduction, damage symptoms etc, to summarize the effect of varroa mite in the bee colonies, and finally to review the progress in the management of the mites in bee colonies.

Morphology

Varroa mites have well defined idiosoma and gnathosoma (Rosenkranz *et al.* 2010) ^[38], and differentiating the sex of the mite is quite simple. The males are smaller in size (0.7mm long and 0.715mm wide), pale yellow in colour with oblong, triangularly shaped. They have longer legs than femalemites (Roth *et al.* 2020; Rosenkranz *et al.* 2010). The females are generally 1.1mm wide and approx. 1.6mm long. They have an ellipsoid, flattened body (Roth *et al.* 2020; Rosenkranz *et al.* 2010) ^[38], are reddish-brown in colour and are having small bristling setae dorso-ventrally.

Table 1: Biology of Varroa mite

Sn. No.	Title	Author	Year
1	Biology and control of Varroa destructor	Rosenkranz <i>et. al</i>	2010
2	Life cycle and control of Varroa mite in <i>A. mellifera</i> (Hymenoptera: Apidae)	Roth <i>et al</i>	2020
3	Honey bee pathology: current threats to honey bees and beekeeping	Genersch	2010
4	<i>Distribution of Varroa jacobsoni Oud on Apis mellifera L during winter in Argentina</i>	Kuenan and Calderone	1997
5	Reproductive parameters of female Varroa destructor and the impact of mating in worker brood of <i>Apis mellifera</i>	Häußermann <i>et al</i>	2020

Life Cycle

Varroa mite is very closely linked to its host and lacks a free-living stage (Genersch, 2010) ^[21]. There are two stages in the life cycle of varroa mite females: A phoretic phase and a reproductive phase (Roth *et al.* 2020). Males and nymphal stages of the mite are short lived and can be found only inside the sealed brood cells (Roth *et al.* 2020).

Phoretic phase

In the phoretic phase the female mite uses the adult bee as the vector and a food source. The adult foraging and swarming bees help in transporting the Varroa females to brood cells for their reproduction (Kuenen and Calderone, 1997) ^[31]. The Varroa female is usually hidden under the sternites of the adult bees. Transfer of *V. destructor* can take place between colonies through robbing, drifting of drones, and worker bee homing errors (Seeley and Smith 2015) ^[44]. The mites suck the haemolymph from both the adult and the larval stages of honey bee.

Reproductive phase

In the reproductive phase the mite enters an unsealed brood cell with a 5th stage bee larva, to lay eggs (Roth *et al.* 2020; Amélie *et al.* 2020). The reproduction of the varroa mites takes place inside the capped worker and drone brood cells although, in the drone cells, the reproductive success of the mite is higher than in the worker cells.

Reproduction

Mature female mites, also known as mother mites or the foundresses enter the brood cells just prior to capping of the cells. The foundresses pierce the cuticle of the larvae to feed, and the same becomes the feeding area of the mite progenies (Roth *et al.*, 2010). The feeding on the brood begins within the first six hours of the cell being sealed, and regular thereafter. The first egg laid by the foundress develops into a male (Häußermann *et al.*, 2020), whereas the second one develops into a female mite that later mates with the male. While feeding on the larvae, the foundresses may transmit different viruses to the larvae (Ramsey *et al.* 2018) ^[40].

At most, a foundress lays approx. of 30 eggs in its lifetime (Akimov and Yastrebtsov, 1984). In the *Apismellifera* (Linnaeus, 1758) species worker brood cells, the Varroa foundress can produce up to five eggs each brood cycle. The foundresses lay the first egg in about 70 hours after capping of the cell (Rosenkraze *et al.* 2010). The sex of *V. destructor* is determined via the arrhenotokous parthenogenesis, as the female mites can produce offspring without mating, i.e., the offspring from the 1st egg will be a male (haploid) mite (Häußermann *et al.*, 2020). Then approximately every thirty hours, the foundresses lay a female (diploid) egg. The number of eggs laid can range from five on a worker pupa to six eggs on a drone pupa in a capped brood cell. The egg hatching and emergence of the mites is followed by the protonymph and the deutonymph stages of the mite (Boecking and Genersch 2008) ^[7].

There should be a total of 35 spermatozoa inside the female spermatheca, and therefore, the males will mate repeatedly. The reproductive stage ends with the mother mite and the mature daughter mites exiting the brood cell with the honey bee. The males and the immature mites are left behind to die in the abandoned cell (Roth *et al.* 2020).

Food and Nutrition

The mother mites provide food to the pupae of the offspring through the tiny hole of pupa. (Morgan *et al.* 2020) ^[34]. The hole is present near the fecal accumulation area for the easy travel between the two areas. The hole

remains open by anti-coagulant proteins present in the mite's saliva (Traynor *et al.*, 2020; Richards *et al.* 2011) [30, 41]. The area for the accumulation of fecal matter created by the bee pupa nearer to feeding hole to avoid pupae hemorrhaging and ultimately drowning the mite (Morgan *et al.* 2020) [34].

Seasonal Incidence

The incidence of Varroa mites is directly proportional to the amount of brood and the colony's size by extension. Colonies with high population density have high infestation rate (Frey and Rosenkranz, 2014) [17] and are therefore beneficial for the mite. After the first infestation of Varroa mites in a new honey bee colony, the mites are able to raise a huge population within a few years (Büchler, 1994; Fries *et al.* 2003) [18, 20]. The number of female mites, ability to reproduce and availability of brood are the factors on which the rate of population growth depends on.

There are, significant differences between the population dynamics in temperate and subtropical/tropical climates with a clear tendency for lower mite population growth under tropical conditions. In the cold and temperate climates, the number of mites may increase about 10 times each year and the infested colonies may collapse within approx. 4 years (Ritter, 1984; Fries *et al.*, 1991) [42]. This lower population growth of the mite is striking as under the tropical conditions honey bee brood is available throughout the year and therefore, mite reproduction is not interrupted like the winter under temperate climatic conditions. As per the research conducted by Nripesh and Ishan, 2020, the varroa mite population was reported higher in the month of March while it decreased in April and May and again increased in June. They observed that the mites were higher in brood cells (54.84% and 52.51%) than in the adult bees (10.39% and 9.59%).

Damage Symptoms

There are very less symptoms showed by colonies with low varroa mite infestation, but more symptoms become visible as their population increases. High Varroa mite infestations can take 3–4 years for their build up and can easily cause scattered brood, crippled and crawling honey bees, impaired flight performance, a lower rate of return after foraging, a significantly reduced weight and a reduced lifespan of worker bees.

Colony symptom is commonly called parasitic mite syndrome which is a condition in which a honey bee colony starts deteriorating and eventually dwindle away and die. The syndrome includes an abnormal brood pattern, sunken and chewed cappings and larvae slumped in the bottom or side of the cell. All these events ultimately cause a reduction in the honey bee population followed by supersedure of queen bees and eventually colony breakdown and death. The mite feeds through a feeding hole present in the 5th abdominal sclerite (Roth *et al.* 2020; Donze and Guerin 1994) [15]. Lipid feeding was recently studied by Ramsey *et al.* 2018 as in earlier studies shown the mite was feed only on the hymenolymph of bees externally. The continuous feeding on the larval, pupal and adult honey bees, weakens them and results in poor immunity (Shen *et al.* 2005) [45].

The loss of haemolymph during the ontogenetic development within the brood cell significantly decreases the weight of the hatching bee (Rosenkranz *et al.* 2010) [38]. The weight loss depends on the number of mother mites present and the amount of mite reproduction, but even a single infestation will result in an average loss of body weight of 7% for the hatching bee (Rosenkranz *et al.* 2010; De Jong *et al.* 1982) [38, 13].

Table 2: Damage caused by Varroa mite.

Sn. No.	Title	Author	Year
1	Behavioral attributes and parental care of Varroa mites parasitizing honeybee brood.	Donze and Guerin	1994
2	<i>Varroa destructor</i> feeds primarily on honey bee fat body tissue and not hemolymph	Ramsey <i>et al.</i>	2018
3	The role of varroa mites inn infection of Kashmir bee virus(kbv) and deformed bee virus(DWV) in honey bees	Shen <i>et al.</i>	2005
4	Weight loss and other damage to developing worker honey bee from infestation with <i>Varroa jacobsoni</i>	De Jong <i>et al.</i>	1982
5	Biology and control of <i>Varroa destructor</i> .	Rosenkranz <i>et al.</i>	2010
6	<i>Virus infections of honey bees Apismelifera. Ital</i>	Tantillo <i>et al.</i>	2015
7	<i>Honey bee viruses</i>	Chen and Siede	2007
8	Prevalance and seasonal variations of six bee viruses in <i>Apismelifera</i> l. and <i>Varroa destructor</i> mite populations in France. Appl	Tentcheva <i>et al.</i>	2004

Joe Mowery (ECMU), and Ramsey (2019) prepared some specimens by placing the feeding mite on the bee body with cyanoacrylate glue. Then, ultra-thin sections were studied through a transmission electron microscope (TEM). They found that the mites were breaking down and feeding on the fat body tissue via extra-oral digestion.

Tantillo *et al.* 2015 [47] reported that the parasitic mite syndrom is transmitted by the mite along with viruses and bacteria. Total 18 viruses are identified still now and 6 of then are most comon and transmitted various diseases in the bees. The most comminly identified viruses reported by Chen and Siede, 2007 [12] are deformed wing

viruses, black queen cell virus, sac brood virus, Kashmir bee virus, acute bee paralysis virus and chronic bee paralysis virus. Among these, deformed wing virus is the most frequent (Tentcheva *et al.*, 2004) ^[48].

Management of Varroa Mite

Two mite per 100 of bee population is the ETL of varrova mite. various management techniques are used by the different apiculturist to keep the population of mite below ETL. Combination of two or more physibile techniques are gives good result for the management of the of bee mite.

Monitoring

Monitoring of bee mites in the colonies is important to decide the necessary steps in controlling the mite population. This can be done by several methods, which includes brood uncapping, sugar rolls and alcohol washes. Mite populations are monitor effectively by alcohol washing (Robyn and Margarita, 2019). Beekeepers should sample at least twice a year, in early spring and in late summer. Beekeepers may also consider taking samples before and after a treatment to determine if the treatment was effective.

Standard sugar roll test is used to count 300 bee population at the same time. Reuter and Spivak 2011 reported four method for monitoring includes Brood uncapping, roll, sticky board and powdered sugar shake. It is also reported that less than 3 per cent infestation is safe as per 2017 consensus.

Cultural Control

This method are the traditional methods adopted by our ancestors that will help to reduce the mite population. It includes maintaing resistance bee population, brood break provision and small cell comb provision (Cameron and james, 2021 ^[10]; Underwood and uribe, 2019) ^[10].

Mite resistant varieties

Breeding mite-resistant bees is a better choice as it cuts the cost of other control methods. In 2016, Greg Hunt, a bee biologist who recently retired from Purdue University in West Lafayette, Indiana, said that you can reduce the use of treatments, increase your survival, and reduce the number of colonies needed to replace every year. In 2011, Andino and Hunt reported that the proportion of damaged mites was a good indicator of grooming behaviors it was presumed that the bees have chewed them.

Also, in a program carried out at Purdue University by Hunt *et al.* 2016, researchers worked with beekeepers from USA's Midwest states. They used the 'mite biting trait of the colonies in a breeding program for the selection of increased *Varroa destructor* resistance.

A study by Morfin *et al.* 2020 ^[33], provides evidence that honey bees selected for mite-biting behavior have reduced *Varroa destructor* infestations.

The honey bees' behavioral traits that might have an impact on the limit of growth of the *Varroa* mite population are), absconding tendencies, hygienic behaviour, high swarming and grooming behaviour. As per the studies of kefuss *et al.*, 2016, it is possible that selected bees with lower mite populations, can be used to breed its genetic material into other honey bee gene pools.

Small cell comb

According to the data obtained by Melissa *et al.*, 2019, that mite reproductive success was significantly reduced in smaller cells in the colonies with higher rates of non-reproduction, delayed reproduction, and male absence, however not in the surviving colonies. However certain studies reveal an opposite result. In a 2011 paper by Thomas D. Seeley and Sean R. Griffin, small-cell combs were once again found to produce no fewer mites than regular-sized combs. This work matches the result of similar experiments reported by Berry *et al.* 2010, and Coffey *et al.* 2010 that demonstrated that small-cell combs in European honey bees do not reduce either mite loads or mite drops significantly compared to hives with similar genetics and similar mite infestations.

Mechanical Control

Varroa mite can be possible to control via mechanical methods effectively by several methodsare as follows.

Mite trapping

Devi *et al* 2019, observed that the infestation of varrova mite is more in brood cell as the size of brood cell is larger than the worker cell under capping. The reproduction also observed more in drone cell. The mite can produced 2.2-2.6 % of offspring per attempt in drone cell which is higher than the worker cell of 1.3-1.4% only. The attractive period of bee mite is 40-50 hours in drone brood but in worker brood it is only 15-30 hours. It indicate that, this techniques is most suitable for the drone cell rather than the worker or queen cell. Underwood and uribe, 2019; Devi *et al.*,2019 reported that under the capping of drone cell the population of mite increase six times than the worker cell population. However, small cells combs cannot reduce *Varroa* infestation in the bee colony (Berry *et al.* 2010).

Screened bottom board

Screened bottom boardsis a natural way to control *Varroa* mites and can lead to a better colony health (Delaplane *et al.*, 2005). This strategy allows beekeepers to monitor how dense pest populations are reaching throughout the

year. Screened bottom boards can also help with the sugar-shake method, which encourages bees to groom the hive of *Varroa* while also grooming the powdered sugar off (Underwood and uribe, 2019; Devi *et al.*, 2019).

Powdered sugar

Grooming behaviour can be enhanced by sprinkling powdered sugar on bees for mite control as a result more mites collected on the bottom boards. Its use can also be effective on the bees removed from the hive equipment, but this is a labour-intensive method, so it is advised to the beekeepers to weigh the costs and benefits while considering this method. As per the studies of Ellis *et al.*, 2009, powdered sugar treatments had no effect in the adult bee population, total brood area, total mites per colony, mites per brood cell, or mites per adult bee.

Biological Control

Entomopathogenic fungi

Varroa destructor has been found to be susceptible to the entomopathogenic fungi, *M. anisopliae*, *B. bassiana*, *Verticillium lecanii*, *Hirsutiella* spp. (Rodríguez *et al.*, 2009). As per Rodríguez *et al.*, 2009 and Ahmed and Abd Elhady, 2013 study, mortality percentage in bee mite is 85% by the application of *Metarhizium anisopliae*. According to the study conducted by Araya *et al.* 2019, under lab conditions, both *Beauveria bassiana* and *Metarhizium anisopliae* can be used against varroa mites without affecting the bees.

Mite predator

Fagan *et al.* 2012 tested pseudo scorpions against bee mite and also observe that there is no harmful effect was on the bee larval population by the application of pseudo scorpions. It is also reported that in a single bee colony maximum 25 predatory creature can be managed for bee mite management, (Ratsch *et al.*, 2018).

Chemical Control

Two types of chemicals were reported for the management of bee mite namely soft chemicals and hard chemicals (Rosenkranz *et al.* 2010; Roth *et al.* 2019).

Soft chemicals

These are the naturally derived substances like essential oils, hop beta acids and organic acids which have no residual effect on the bee colony and hive parts. So before the application of hard chemicals such chemical should be applied for mite control (Devi *et al.* 2019).

Soft chemicals have advantages over hard chemicals as they reduced potential to build resistance of the mites towards treatments, they can be used in organic farming, and each chemical's components are found within the hive or food we consume on a regular basis like thyme, beer, spinach, and honey. Soft chemicals also do not contaminate the hive like the synthetic chemicals. They do not result in miticide build up in the comb followed by its resultant issues with the health of the queen and the brood.

Formic acid.

Bees can effectively penetrate the wax capping and easily release formic acid which is present in the venom of honey bees with higher concentration and kill the reproducing mite population. It is a natural component of honey produced inside the worker honey bees. (Devi *et al.* 2019). It is used as a fumigant (Elzen *et al.* 2004)

A study conducted by Eliza, and Dumitru, 2022, in which they brushed all capped brood with formic acid of 65% concentration in one and two applications. The obtained results show incredibly significant differences between the treated and control groups in terms of infested cell percentages evaluated in the July–August period. Also, according to the experiments of Rafael *et al.*, 2014, in the group of colonies treated with formic acid, 86% of mite mortality occurred in capped brood cells.

Oxalic acid.

The vegetable crop like kale, beet and spinach is a good source of oxalic acid. It is an organic compound having acaricidal property. It can be used as vapor, trickling and spraying or used as crystals and is preferred during autumn and winter months (Roth *et al.* 2020). The basic way of applying oxalic acid is by trickling. In this, the oxalic acid solution is trickled with a syringe on the top bars of the frames. It is most effective against the broodless period because it does not penetrate the cell capping (Underwood and uribe, 2019; Devi *et al.*, 2019).

Thymol.

Thyme plant is a good source of thymol, the essential oil extracted from the plant effectively controls the varroa mite control (Underwood and uribe, 2019; Devi *et al.*, 2019). The essential oils are believed to be effective as they act on the neurological factors of the *Varroa* mites (Roth *et al.* 2020). Thymol is a highly efficient and safe treatment against the *Varroa* mite if used as per recommendation. It is most effective against the mite population present on the adult bees. It cannot penetrate the cell capping hence not effective against the mite present on the brood population (Devi *et al.* 2019).

Hops beta acids.

Potassium Salts of Hops Beta Acids (K-HBAs) is intended to provide another option for beekeepers to combat Varroa mite and to avoid the development of resistance toward other chemicals. This biochemical is a naturally occurring substance with minimal toxicity and a non-toxic mode of action against varroa mite. There are numerous advantages to using HBAs, including reduced toxicity to other organisms, effectiveness in small quantities, and reduced environmental impact. Multiple applications is required throughout the rearing programme (Underwood and Uribe, 2019)

Hard Chemicals

Synthetic miticides can kill up to 95% of the mite population. They can be found under the names of fluvalinate (Apistan), amitraz (Apivar), and coumaphos (CheckMite+). The advantage of these synthetic treatments is their high error margin. However, it is always important to closely follow the label while handling these chemicals as they can harm peoples and the bees.

It is observed that the mite found resistance against some chemicals like fluvalinate and coumaphos (Maggi *et al.* 2010; Roth *et al.* 2020) and also accumulate the residues in wax. It can showing harmful effect to bee wax and leads to nosema disease infestation (Devi *et al.* 2019).

Summary and Conclusion

Varroa mite is still a major issue with the beekeepers, which feedson the bees for lipids and hemolymph. As we cannot block the entry of the mites to the beehives, by continuous monitoring and management can help reduce the mite population. According to the studies, beekeepers can adopt (a) cultural methods that include methods like rearing resistant varieties, small cell comb, brood break, (b) mechanical methods that include mite trapping, screened bottom board, powdered sugar, (c) biological methods that includes the use of entomopathogenic fungi and mite predators. In extreme cases, the use of chemical is acceptable with preference to soft chemicals, that includes oxalic acid, formic acid, thymol etc., over the hard chemicals that includes amitraz. Bee colonies can be save by the regular management of bee mite. Combination of IPM approach, is most effecient tool for the management of bee mite population.

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