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Varroa destructor AND A THREAT OF VIRAL INFECTIONS OF THE HONEYBEE (*Apis mellifera* L.)

(review)

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Abstract

Bee viral infections worldwide leading to colonies' depopulation have emerged as a threat to bee keeping. To date, nearly 20 RNA viruses, of *Dicistroviridae*, *Iflaviridae*, *Nodaviridae* families mostly, were detected in honeybee *Apis mellifera* (O.F. Grobov et al., 2006; C. Runckel et al., 2011). Also DNA viruses have been found, e.g. iridovirus (*Iridoviridae*), potentially causing losses of bee colonies (J.J. Bromenshenk et al., 2010), *Aphid Lethal Paralysis virus* (*Dicistroviridae*), *Big Sioux River virus* (*Dicistroviridae*), *Lake Sinai Virus strain* 1 and 2 (*Nodaviridae*) (C. Runckel et al., 2011) however, their role in bee mortality has yet to be understood. The most important bee viruses known to date are deformed wing virus (DWV), acute bee paralysis virus, (ABPV), chronic bee paralysis virus (CBPV), Kashmir bee virus, (KBV), sacbrood virus, (SBV), Black queen cell virus (BQCV). These viruses can persist in honey bees (*Apis mellifera* L.) without apparent symptoms, however, *Varroa destructor* infestation causes a viral epidemic, diminishing bee colonies. The range of *V. destructor*, the main viral infections' vector (D. Tentcheva et al., 2004), was confined to that of *A. cerana* being ecologically balanced. However, not long ago this mite crossed the species barrier from the Asian hive bee *A. cerana* to our own Western honey bee *A. mellifera* (R.S. Poltorzhitskaya, 2008). The introduction of *V. destructor* into the *A. mellifera* population has become one of the major contributing factors to colony collapse disorder (D. van Engelsdorp et al., 2008; R.M. Johnson et al., 2009; F. Nazzi et al., 2012). Moreover, the mite Varroa affects the immune response and metabolism of honey bees and allows its vectored viruses to propagate to high viral loads. At present there is an objective need for a closer look into bee viruses implicated in bee colony losses reported worldwide. So far as Varroa mite is an obligate parasite of *A. mellifera* during whole ontogenesis, the Varroa control notably ensures the well-being of bee colonies. In this review, an overview of the world distribution and the impact of the major viruses (DWV, ABPV, CBPV, SBV, BQCV, KBV) on bee health and colony survival is presented. We also discuss approaches to virus control. Overall, the strategy combining new Varroa management practices (A.A. Fedorova et al., 2011), selection of Varroa-resistant bees and novel treatments against viruses will help sustain the honey bee population.

Keywords: *Apis mellifera*, *Varroa destructor*, viruses, viral infection transmission, vectors.

To date, nearly 20 RNA viruses, of *Dicistroviridae*, *Iflaviridae*, *Nodaviridae* families mostly, were detected in honeybee *Apis mellifera* [1-3]. DNA viruses also have been found — iridovirus (*Iridoviridae*), potentially causing losses of bee colonies [4], *Aphid Lethal Paralysis virus* (*Dicistroviridae*), *Big Sioux River virus* (*Dicistroviridae*), *Lake Sinai Virus strain* 1 and 2 (*Nodaviridae*) [2]. However, their role in bee mortality has yet to be understood.

Active replication of most viruses in insects usually results in negative changes of physiological parameters and behavior up to honeybee colony losses [5-8]. Latent viruses can persist in some individuals or in bee family as a whole and not cause the death [9-11]. Importantly, some viruses when influenced by definite but not clearly understood factors can provoke a decrease in bee cold resistance, queen bee reproductive activity, flying activity of bees and nectar collection [12].

Undoubtedly, viral infections are dangerous under bee infestation with *Varroa destructor* mite, the vector of most harmful viral infection [10]. When biting, an infected mite transmits a causal agent to bee. Varroa mite is an obligate ectoparasite of *A. mellifera* at all stages of ontogenesis. Initially, Asian bee *A. cerana* was the host species, but not long ago this mite crossed the species barrier, and now *A. mellifera* bees are also infected in natural habitats [13, 14].

A. cerana and *V. destructor* were ecologically balanced so that the mite did not cause death in the bees. First, the mite can not reproduce in cells with worker *A. cerana* bees [15, 16], and the reproduction occurs in drone cells only. Secondly, the *A. cerana* imagoes effectively remove Varroa mites due to active grooming [16]. Thirdly, at high infection load the drone pupas are less viable, not able to break cocoon and dye, and the bees then ignore these cells [17, 18]. Thus about 25 % of mites in the bee colonies are eliminated.

However, lack of defensive behavior in *A. mellifera*, with the exception of less effective grooming, leads to low immunity, a decreased body weight, disorders in water balance and carbohydrate metabolism, and reduced the life expectancy. Finally, bee viability decreases causing colony death or collapse [19-23].

Viral infections in *A. mellifera* were underestimated until *Varroa* introduction [21]. Nevertheless, high viral infection rate (up to 90 % of bees in some colonies) has been detected by RT-PCR. A combined infection of 5-6 different viruses can be found in highly mite-infested bee colony [29]. A definition of «bee parasitic mite syndrome» is used for symptoms of mite-infested bees with viral pathology [25]. It was shown experimentally that inoculation of virus particles in the bee hemolymph and suppression of the immune response by the Varroa mite reduce the defenses both in a bee and the bee clony, and activate latent viral infections [26].

Of those found to date, the most important bee viruses are deformed wing virus (DWV), acute bee paralysis virus (ABPV), chronic bee paralysis virus (CBPV), Kashmir bee virus (KBV), sacbrood virus (SBV), and black queen cell virus (BQCV).

Deformed wing virus. DWV (*Iflaviridae*) is found worldwide [27, 28] including Russia [29, 30] and Azerbaijan [31]. DWV is genetically close to *Kakugo virus* found in aggressive bees in Japan [32, 33]. In *Kakugo virus* and DWV RNAs are 97-98 % homologous [32]. Currently, *A. mellifera* is considered the main host species for DWV disseminated due to *V. destructor* [10, 34]. DWV also was detected in *A. cerana*, *A. florea* [35, 36] and in bumblebees (*Bombus terrestris*, *B. pascuorum*) with deformed wings [3]. DWV was isolated from *V. destructor* [21, 37-39] and *Tropilaelaps mercedesae* [40, 41], the ectoparasitic mites of honeybees. These are the vectors, especially *V. destructor* which plays important role in DWV transmission [21, 26, 42, 43].

DWV is also detected in *Aethina tumida*, the small hive beetle providing DWV replication. There are reports of DWV transmission from *A. mellifera* to *A. tumida* [44] and bumblebees [28]. DWV is avirulent in the bees not infested by *V. destructor*. Latent DWVs do not cause clinical symptoms [21, 45-47]. DWV can be transmitted transovarially via drone sperm, and between colonies at swarming [45, 48].

Characteristic DWV symptoms under high mite infestation are rudimentary and crumpled wings, bloated bellies, and discoloration. These bees are not viable and die 67 hours after they emerged from their cells that leads to weakening bee colonies [25, 49, 50]. Evidence for the *V. destructor* as a vector for DWV has been obtained [21, 51]. In recent experiments it was shown that the presence of viral (–)RNA (the replicative form of DWV genome) in mite causes clinical DWV symptoms in pupas. In the body of a mite from died bee with DWV pa-

thology the viral particles can reach 10^{10}-10^{12} in number. Thus the manifestation of DWV syndrome in bees depends on DWV amplification and accumulation in mites not less then on the virus transmission [43]. When studying DWV location in the mites, the viral particles were found only in the intestinal lumen but no evidence for replication was obtained. Probably, in mite population the DWV is replicatively inactive. For elucidation, the mites must be investigated in the colonies where the bees with deformed wings emerge.

In Europe, depending on the season, up to 100 % of honeybee colonies may be infected with DWV [10, 52]. The presence of DWV together with *V. destructor* in bee colonies before winter period is likely to cause the death in winter time [53-55]. In the absence of mites the DWV infection is symptomless [45], but under the Varroa infestation DWV is activated causing death in honeybees. Before the *V. destructor* attacked Europe in 1970-1980, no manifestation of DWV infection was reported [36]. But nowadays the DWV is considered one of the main reasons for the collapse in the mite-infested bee colonies.

DWV infection is always associated with the presence of *V. destructor* as its vector [22, 37, 51]. In Thailand and France the DWV monitoring has shown that the virus can constantly be present in all mite individuals [10, 56]. The presence of DWV was revealed in 69 % and 90 % of infested bees in Poland and England, respectively [57].

It is statistically proven that bee infestation by *V. destructor* in the summer leads to DWV appearance in the autumn. In 4 year survey of 1,250 honeybee colonies in Germany a relationship was found between winter death rate, *Varroa* infestation level and the DWV titer in bee body [47, 58, 59].

DWV can also infect wild bees *A. florea* and *A. dorsata* [60]. It is assumed that the DWV and Varroa destructor virus-1 (VDV-1) can cause degeneration of the ovaries in queen bees [61]. When laying DWV infected eggs, the queen bees transmit the virus to offspring causing symptomless carrier state [45, 62]. DWV was detected in faeces of queen bees [63]. Obtained data [64] are in line with another report about DWV detection in the faeces of worker bees [65].

Varroa mite also is a carrier of VDV-1 virus [66], RNA of which is 84 % identical to the RNA of DWV [66, 67]. Moreover, the recombination between VDV-1 and DWV is possible [68], producing recombinant viruses such as VDV-1_{DVD}, which are better adapted to the horizontal transfer via mite biting and effectively avoid the immune control of the bee host. They also can replicat to larger loads than DW or VDV-1 that may be indicative of higher virulence of the recombinants for the bees [68].

Acute bee paralysis virus. ABPV is genetically close to KBV and Israeli acute paralysis virus (IAPV) (*Dicistroviridae*) [69, 70]. ABPV can infect both brood and worker bees. Naturally, ABPV persists in bees without clinical manifestation and does not cause death [8]. Presumably, ABPV can be transmitted via the saliva when feeding larvae and producing beebread. At high infection rate the larvae usually die before sealing, but in case of surviving no clinical manifestation of ABPV occurs in the adults.

ABPV detection in *Varroa* suggests an involvement in ABPV transmission and dissemination [9, 10, 56]. In addition to acting as a carrier, the mite is able to activate latent infections caused by ABPV. Significant virus accumulation in dead bees with ABPV syndrome and high rate of mite infestation suggests that Varroa can activate the virus replication so that it causes death of the bees [71]. Importantly, an injection of phosphate buffer into bee hemolymph also activate ABPV replication, hence the Varroa mites are not the only agent activating latent ABPV [72].

Both ABPV and Varroa mite seem to cause the mass losses of bee colonies in Europe [9, 73]. ABPV is one of two the most common viruses in Austria [52]. For a long time the ABPV was detected in apparently healthy honeybees in Britain [35]. ABPV was found in honeybees in France, Italy, Canada, Chinese, United States [72], and in New Zealand. Currently, ABPV is expanding worldwide due to the *A. mellifera* expansion [35, 36].

Since the *V. destructor* appeared in Europe, the high rate of ABPV infection was detected in the heavily infested bee colonies with dead sealed and unsealed brood. This was first considered in Russia and Germany in the late 1970s and early 1980s [74]. Then similar data were reported from Netherlands, Italy, former Yugoslavia, France [71], Hungary, Austria [52], Denmark [37] and USA [72]. In Germany and Holland in dead honeybees from the colonies of low, medium and high mite infestation the ABPV frequency was 3 %, 44 % and 80 %, respectively.

In France ABPV was found in 58 % of adult bees, and in 23 % of pupas and apparently healthy bees, while the frequency of ABPV-infected *Varroa* mites was 36 %. Viral infection was more frequent in infested colonies in the late summer and autumn that correlated with the peak in Varroa population [10]. In Denmark [75] the ABPV infection was detected in 14 % of bee colonies, in contrast to data obtained in France and Austria for clinically healthy and sick bees (58 % and 68 %, respectively) [52]. In the opinion of Danish researchers, these may be due to organic acids used against the mite, which are less effective against varraosis so that bees must withstand higher infestation resulting in higher natural death among ABPV infected bees. In Denmark the ABPV frequency was 73 % in 2004 and 80 % in 2005 [76]. In this investigation the relationship was found between infection, infestation and winter death in the colonies. A reliable dependence of bee winter death on ABPV frequency before hibernation was shown for 2005-2006 season but not for 2004-2005 season. However, the bee death in winter correlates with the rate of bee infestation in both seasons. Reasonably, the latent ABPV can be transmitted and activated by the *Varroa* mite that is a cause of bee death in winter [76].

Kashmir bee virus and Israeli acute paralysis virus. KBV was first described in 1977 in *A. cerana* [77]. KBV, a RNA virus, when inoculated into the bee hemolymphm, replicates to high titers [78]. Bees infected via hemolymph died within 6 days, but insects which ate KBV preparation remained apparently healthy [78]. Hence, the lethal effect of KBV depends on transmission routes [78, 79]. In these the *Varroa* mite is of key importance. KBV was first isolated from homogenate of worker bees *A. mellifera*, experimentally infected with extract of *A. cerana* bees from Kashmir (India) [78]. Detection of KBV in *A. mellifera* Australian population is extremely interesting as *A. cerana*, which seems to be the main host bee for KBV, does not inhabit this continent. Then KBV was discovered in *A. mellifera* from Canada and New Zealand [80], on Fiji [81], in USA [49], Europe and Oceania [35, 36, 82]. Currently, KBV is reported in *A. cerana* [35, 77, 78], *A. mellifera*, bumblebees (*B. terrestris*, *B. pascuorum*) and wasps (*Vespula germanica*). In honeybee populations of North America and New Zealand the KBV infection prevails compared to other viruses [72, 83, 84], though in Europe KBV is rarely found [10, 52, 82, 85].

KBV attacks the bees during whole ontogenesis and usually persists latently in the brood.

IAPV which was isolated in Israel from larvae inoculated with homogenized dead bee, is another dangerous virus closely related to KBV [86]. As its symptoms were similar to those under acute paralysis the virus was called Israeli acute bee paralysis virus (IAPV). The virus is widespread in the Middle East

[86], Australia, USA [87-89] and rarely found in Europe [90].

KBV and IAPV (*Dicistroviridae*) are closely related. Together with ABPV they form a common genetic complex with similar transmission routes. Remaining latent in bee larvae, they cause rapid death of adult insects with characteristic clinical symptoms. Genetic analysis of KBV and ABPV revealed about 70 % homology but also some differences [91].

ABPV, KBV and IAPV at low titers can permanently persist in bees without clinical manifestations [72, 89]. When KBV and IAPV titers reach a critical level the infected bees die [77, 86, 88]. An increase in titers in bee hemolymph under natural infection is related to *Varroa* mite as both vector and activator of virus replication [49, 92, 93].

Research of KBV and IAPV transmission routs [42, 51, 94] showed an important role of *V. destructor* in KBV pathogenicity, but the exact mechanisms of disease development still remained unstudied [42]. It is believed that *V. destructor* suppresses the immune defense in bees, resulting in the activation of resident viruses [19]. In other opinion, the *V. destructor* is a vector, which directly transmits KBV to pupas, as KBV was found in the saliva of the mite [42]. Furthermore, mite infection with KBV and transmission to brood has been proved experimentally [95]. Estimated efficiency of KBV transmission to brood by *V. destructor* amounted to 70 %, when the efficiency of mite-to-mite KBV transfer or the rate of infecting mite from brood was 51 %. KBV plays a key part in death of the mite-infested bee colonies [72, 77]. Also IAPV virulence is probably due to *V. destructor*. The IAPV presence is a marker of bee colonies collapse in USA. The collapse signs are as follows: there are no dead bees at the bottom of the hive, or next to it, bees left brood and queen, weight of worker bees in the hive critically reduced despite of enough feed [96]. Note, the IAPV is also common in Australia, but there is no collapse of bee colonies. Study of bee collapse in USA [97] and bee death in winter with no signs collapse in Germany [76] revealed a sophisticated relationship in ABPV-KBV-IAPV complex in which *V. destructor* is involved as the activator of latent infection. These three viruses differ in geographic distribution [98], and that is why IAPV or KBV can cause bee death in USA while ABPV has lethal effect in Europe.

IAPV was shown to integrate into bee genome. A fragment of IAPV genome is found in the genome of 30 % of Israel bees [86]. IAPV-specific sequences are also detected in *Varroa* genome. Moreover, the bees with integrated IAPV genome possess resistance to this virus [86].

Black queen cell virus. BQCV was first isolated from in blackened larvas and pre-pupas from black cells [78]. BQCV affects mainly larvae and pupae queens in sealed cells. Affected larvae are pale-yellow colored and covered with sac-like skin similar to sacbrood. BQCV replication in queen pupas causing blackening and rapid death. Worker bees also can become infected, but with no symptomes. Moreover, when BQCV enters the bee body via alimentary tract it does not replicate.

BQCV is found in North America, Europe, Oceania, Asia, Africa, Midle East ad Azerbaijan [31, 35, 36]. After 5 year studies in Beltsville (MD, USA) the BQCV was shown to be the second of mostly common bee viruses after DWV [27]. In Australia BQCV is the most frequent causal agent leading to queen death during development.

When adults and pupas were compared [10], the BQCV was found in adult bees, preferably in spring and summer.

A relationship occurs between BQCV infection and infestation by microsporidia *Nosema apis* so that the BQCV frequency in the territory increases as the *N. apis* expands. BQCV replication rate in the presence of *N. apis* infesta-

tion is much higher.

It is assumed that BQCV is transmitted to the queen via royal jelly from bee-nurse. *N. apis* affects intestine providing BQCV infection. In all parts of England and Wales the worker bees infected by BQCV were co-infected by *N. apis* [8]. In Austria, the *N. apis* was found in 78 % of BQCV-positive samples from apiaries, and in 75 % bee colonies infected by *N. apis* the BQCV was also detected. Similar data were obtained in France [10].

It has been suggested that the Varroa mite can serve as a vector for BQCV. BQCV detection in the mite body on apiaries in Thailand confirms this hypothesis [56], while in other studies [10] the virus in varroa mite has not been found.

Chronic bee paralysis virus. Earlier tracheal mite *Acarapis woodi* was considered the cause of the bee paralysis, but at the end of the 1960s a viral etiology of adult bee paralysis has been shown with the CBPV as causal agent. Currently CBPV is revealed in worker bees practically worldwide except South America [35, 36]. CBPV at low loads is often found, together with ABPV, in apparently healthy bees. Chronic paralysis virus is less virulent compared to ABPV, so that at CBPV infection it takes several days to cause the death of the bee, whereas at ABPV infection the insect dies for one day.

Under CBPV infection there are usually two types of symptoms. The most pronounced ones are trembling body and wings, crawling along the ground because of the inability to fly, bloated belly and wings kept apart. Other symptoms are loss of hair and a darker appearance. Such individuals are expelled from the hive. Both types of the symptoms can be observed in the same bee colony.

When assessing CBPV infectivity, the virus was injected into the bee hemolymph, applied on the body surface, or added to the feed. It was found that CBPV can easily penetrate through the cuticle in the absence of hair, but in the case of oral infection the virus propagation in the body is minimal and does not lead to death in bees. Tightness in the hive makes the penetration easier. CBPV infection occurs in the presence of two factors. The first factor is bad weather when bees do not fly out of the hive. This explains the higher prevalence of CBPV in France [99]. The second factor is related to used beekeeping technology. Thus, the increase in the area of sunflower crop in France and, as a result, abundant monofloral pollen, led to a rapid decrease in internal hive space that has not been extended timely resulting in the colony death with the typical chronic paralysis symptoms [100]. CBPV is distributed in the world unevenly. In Britain CBPV is very frequent and causes bee colony losses [8], in Austria CBPV is found in 10 % of bee colonies [52], and in France the virus persists in 4 % of bee colonies. Importantly, seasonal dynamics is not characteristic of CBPV [10]. Transcuticular penetration of CBPV is common. In Thailand and France, when the bees and Varroa mites were surveyed to estimate the presence of CBPV, the virus was found in the bees but not in the mites [27]. In another study carried out in France, CBPV was detected in ants (*Camponotus vagus* and *Formica rufa*) and in the mite *V. destructor*, with the CBPV replicative RNA form detected in *C. vagus* and *V. destructor*, which proves the latter's role as a CBPV vector. CBPV detection in *C. vagus* suggests the possible transmission by the ants, though with no direct evidence. Ants can be infected by eating infected bees, and bees and ants can also be infected by eating honeydew of green fir aphids *Cinara pectinatae*. However, to date CBPV has not been found in aphids. Thus, to infect ants, there are still unknown CBPV reservoirs [101].

Sacbrood virus. SBV is widespread in honey bee populations on all continents [35, 36]. The virus affects the bees at all stages of the life cycle, but the 2-day brood is most affected. Viral infection in adult bees develops without

clinical manifestations, but shortens the life of individuals. SBV spreads within the hive as the bees, attempting to remove the infected larvae, accumulate the virus in salivary glands and then contaminate food. The food can be used to feed brood or exchanged between individuals. Young larvae are infected by eating infected food. SBV replication begins in larvae and results in its yellowing after sealing brood. With the progression of the disease the cuticle gets tougher and the larva is unable to pupate. The large amounts of virus accumulate under the larval cuticle [1, 102].

Usually the SBV infection is seasonally dependant with domination in spring and summer [8, 10]. At SBV infection, similar to foulbrood, worker bees usually remove or eat the dead larvae thus promoting further SBV expansion in the hive. In some colonies the hygienic behavior may be less strict, and healthy insects can recognize the latent SBV carriers prior to an increase of viral loads in the mummified bees and manifestation of the symptoms [103].

In numerous publication the mite Varroa involvement in SBV transmission is reported based on identification of the virus in flying bees with high infestation by the mite [52, 73], and also in the mites themselves [10, 42, 56].

Prevention of viral diseases in bees. Experimentally, ABPV, BQCV, CBPV, DWV, KBV and SBV are detected in the pollen (BQCV and DWV are also found in honey), ABPV, CBPV, KBV and SBV are present in beebread but absent in the saliva of bees and royal jelly [63]. As to other data, KBV and SBV were reported in royal jelly, honey and pollen [42].

Detection of viruses in *V. destructor* indicates its key role in the transmission of the causal agent in bee colonies [10, 21, 32, 51, 56, 66]. Harmful pathologies due to ABPV, CBPV, slow paralysis virus (SPV), BQCV, KBV, cloudy wing virus (CWV), SBV and DWV, leading to clinical symptoms and death have been recoreded in bee colonies under high level of mite infestation [10, 104]. Additionally, the rate of virus transmission was shown to depend on mite number in the cell and, consequently, on the total infestation level in the colony. Moreover, in case of uninfected mites in the cell they become infected via hemolymph of infected pupa. Undoubtedly, high mite infestation threatens beekeeping worldwide.

Currently, the development of methods to control mites, bee (*A. mellifera*) breeding for resistant to the mite, and bee treatment against the viral infections are considered as effective ways. These approaches should be used in combination, as in the metagenomic studies of collapsed and survived bee colonies the *V. destructor* together with IAPV and DWV were proved to be the main markers of the collapse [91].

Varroa abundance must be under control to decrease the losses of honeybee colonies [105]. As the mite activates latent viruses, affects the immunity, and causes metabolic disorders, the Varroa control provides the wellbeing of bee colonies. In the absence of the mite and and favourable conditions viral infections in bees are harmless [106]. Bee viruses are found in drone body [95] and sperm [63, 107], and in queen spermatheca (68), thus indicating vertical rout for virus transmission to offspring and probable infection of queen at mating. Since the bee queen during the life lays tens of thousands of eggs, vertical transmission of infection can be a serious risk to bee colonies, threatening its survival and indicating the importance of a regular and timely replacement of queens.

Attempts to breed Varroa-resistant bees are not yet successful. A 6 year survey of 150 honeybee colonies, with no acaricides applied and frees swarming, revealed that 3 years after the observation began the bee death in winter reached 80 %, but decreased to 12-18 % over the next 2 years. Finally, only 11 bee colonies

remained [108]. In France during 7 year monitoring of 82 bee colonies those treated with acaricides and not treated were compared. According to mortality during the winter the colonies did no differ significantly, but the bees from untreated colonies collected less nectar (by 41 %). Thus, in mite-resistant bees the honey production is lower that are not economically profitable [109].

Recently, the treatment of viral infections in bees using small interfering RNA (miRNA, siRNA) due to posttranscriptional silencing seems to be promising. Small interfering RNAs, binding to viral RNA, lead to virus degradation [110, 111]. The viral RNA, when replicating with dsRNA formation, is a source of miRNA [112, 113]. Recently, the gene knockout was used against IBPV infection good effect with a decrease of percent of bet colony losses [114). It was found that viral dsRNA, when fed to bees, activates the degradation of IBPV RNA. However, such products are costly, and it is difficult to provide their targeted delivery to the organs and tissues of the insect. A similar approach was used for the relief of the DWV symptoms. In the bees fed with relevant dsRNA the DWV replication was repressed [115]. RNAases are another potentially effective agent to combat viral infections in bees. For example, RNase can inactivate ABPV when the virus suspension is pre-incubated in vitro. This suspension became harmless to larvae when inoculated [115]. However, a complicated problem of delivering these preparations to bee hemolymph still remains actual.

So, the most important of viruses found in honey bees are deformed wing virus (DWV), the acute paralysis virus (ABPV), chronic paralysis virus (CBPV), Kashmir virus (KBV), the sacbrood virus (SBV), and black queen cell virus (BQCV). ABPV, BQCV, CBPV, DWV are detected in pollen, BQCV and DWV can also be found in honey, and ABPV, CBPV, KBV and SBV are reported in beebread, honey, pollen and royal jelly. Correlation between high virus loads and *Varroa destructor* infestation indicates that the mite serves as agent predisposing bees to viral infection or activation of latent viruses. Under per or inoculation the viruses in most cases are not lethal for bees, whereas they lead to mass death in a short time when vectored by *V. destructor*. Bedides, to prevent the manifestation of bee parasitic mite syndrome, it is necessary to take into account local climate condition and used beekeeping rechnologies.

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