DOI 10.32900/2312-8402-2025-135-93-106
UDC 57:595.799:638.157

EFFECTIVE STRATEGY FOR CONTROLLING THE NUMBER OF ECTOPARASITIC MITES VARROA DESTRUCTOR ON HONEYBEES *APIS MELLIFERA* L. 1758 FOR APPLYING AN INTEGRATED APPROACH
(REVIEW)

Irina MASLII, candidate of Veterinary Sciences, senior researcher,
https://orcid.org/0000-0002-8671-3356
Livestock farming institute of NAAS of Ukraine,
Kharkiv, Ukraine

Apis meliffera (honey bee) is one of the economically valuable species, representatives of the Class Insecta. The biggest threat to the bee Apis mellifera remains the ectoparasitic mite Varroa destructor, which causes many health problems, the consequences of which can lead to the collapse of families. The influence of the parasite on swimming may be due to the susceptibility of honeybees to infectious diseases due to their relative proximity and high frequency of social interactions within their family. However, other factors, including environmental conditions related to the parasite's life cycle, as well as the life expectancy and intensity of mite development, can increase its negative impact. Scientists ' observations include increased acaricide resistance in the Varroa population and lower treatment thresholds, suggesting that ticks or pathogens they can transmit to bees are becoming increasingly virulent. Weak families with a high prevalence of infestations contribute to the dispersal of ticks and the transmission of diseases in stronger and healthier nests. Harmful effects of parasitization V. destructor and the effects of acaricides on bee colonies have prompted beekeepers to look for sustainable approaches to tick control. To achieve this goal, individual beekeepers sought to breed V. destructor-resistant honeybees using different selection criteria.

The social behavior of insects has led beekeepers to address their intra-specific and interspecific relationships, focusing on internal behavior to reduce the spread of mites. on honeybees. The efforts of many scientists to find means and measures that will help reduce the extent of infestations and control ticks at a safe level for bees were discussed.

Current scientific directions for studying the social behavior of insects and the use of individual signs of bee behavior in the fight against this parasite are outlined.

Keywords: Varroa mite, bees, acaricides, behavioral reactions

ЕФЕКТИВНА СТРАТЕГІЯ КОНТРОЛЮВАННЯ ЧИСЕЛЬНОСТІ ЕКТОПАРАЗИТАРНОГО КЛІЩА *VARROA DESTRUCTOR* НА МЕДОНОСНИХ БДЖОЛАХ *APIS MELLIFERA* L. 1758 ЗА ЗАСТОСУВАННЯ КОМПЛЕКСНОГО ПІДХОДУ
(ОГЛЯДОВА)

Ірина МАСЛІЙ, к. вет. н., ст. н. співр.,
https://orcid.org/0000-0002-8671-3356
Інститут тваринництва НААН, Харків, Україна

Apis meliffera (бджола медоносна) є одним із господарсько цінних видів, представників класу Insecta. Найбільшою загрозою для медоносної бджоли Apis mellifera залишається ектопаразитичний кліщ Varroa destructor, який викликає безліч проблем зі здоров'ям, наслідки не вирішення яких може призвести до колапсу сімей. Вплив пливу, який чинить паразит може бути обумовлений сприйнятливістю медоносних бджіл до інфекційних захворювань через їх відносну близькість і високу частоту соціальних взаємодій в межах їх сім'ї. Однак інші чинники, включно умови довкілля, пов'язані з життєвим циклом паразита, а також тривалість життя та інтенсивність розвитку кліща, можуть збільшити його негативну дію. Спостереження науковців включають підвищення стійкості до акарицидів у популяції Vappoa та зниження порогів обробки, що свідчить про те, що кліщі або патогени, що вони здатні передавати бджолам стають все більш вірулентними. Слабкі сім'ї з високою екстенсивність інвазії сприяють розсіюванню кліщів і передаванню хвороб у сильніші і здоровіші гніздах. Згубні наслідки паразитування V. destructor та вплив акарицидів на бджолині сім'ї спонукали бджолярів до пошуку стійких підходів для контролю над кліщем. Для досягнення цієї мети окремі бджолярі прагнули розвести стійких до V. destructor медоносних бджіл, використовуючи різні критерії відбору.

Соціальна поведінка комах спрямувала увагу бджолярів звернутися до їх внутрішньоспецифічних та міжспецифічних відносин, роблячи акцент на внутрішній поведінці, щоб зменшити поширення кліща. на медоносних бджіл. Обговорено зусилля багатьох вчених щодо пошуку засобів і заходів, які сприятимуть зниженню екстенсивності інвазії та контролю кліща на безпечному для бджіл рівні.

Окреслено актуальні наукові напрями дослідження соціальної поведінки комах та використання окремих ознак поведінки бджіл у боротьбі з цим паразитом.

Ключові слова: кліщ Varroa, бджоли, акарициди, поведінкові реакції

The honey bee, *Apis mellifera*, plays an important role in modern agriculture. In addition to honey production, insects provide critical ecosystem services, primarily pollination, for a wide range of valuable crops. However, over the past half-century, honeybees have experienced increased stress, which has led to a constant increase in the mortality rate of bee colonies in the world. The factors behind this increased mortality have not yet been fully elucidated. Changes in land use, cultivation and agricultural methods; new pesticides and their larger applications; more intensive beekeeping; exotic parasites and the spread and growth of honeybee pathogens have been suggested as the main factors contributing to their mortality.

The decline in insect numbers seen in previous years has prompted increased awareness and efforts to maintain their survival and the vital role they play in stabilizing the ecological balance of various ecosystems.

Numerous reviews have been published covering the biology of the *Varroa* mite, social immunity *A. mellifera*, history of acaricide use and control, literature on the effectiveness of various treatments available to control mites in honey bee families (Cremer, S. et al., 2007; Mondet, F. et al., 2014; Traynor, K.S. et al., 2020).

Thus, this review focused on:

- study of the harmful effects of *Varroa* mites on European honeybees;

- justification of modern means, methods and methods of mite control and their limitations;

- identifying opportunities for more sustainable methods of controlling ectoparasites.

The aim of the study is to assess the biological significance of the *Varroa* mite in the life of bees, to determine its role as the main factor of increased mortality of bee colonies in the world, as well as to outline promising areas for further scientific research aimed at effectively combating invasion and minimizing harmful effects on bee health.

Materials and methods. The methodological tools included both general scientific methods-logical analysis and synthesis, classification and systematization, generalization, and special ones – problem-chronological and source-scientific and terminological analyses, as well as analysis of literature sources, which was carried out in the form of a systematic review study by searching publications in the databases Scopus, Web of Science, Google Scholar, etc. The review included works in English published mainly in recent years in accordance with certain criteria. The systematization of available scientific data was carried out in order to generalize modern knowledge about existing measures for the treatment of varroasis, effective and safe medicines, which can become the basis for the formation of research methodology in this direction in the conditions of Ukraine, taking into account international experience.

Research results. Scientists and beekeepers are developing approaches to controlling the spread of the mite *V. destructor*, because despite substantial evidence of the need for tick control, no effective solution has been found (Dietemann et al., 2012 Wagoner et al., 2020).

Much attention has been paid to the evolutionary biology of V. destructor and the interaction between the host and parasite. It is known that the tick feeds mainly on the fat body, as well as on the hemolymph of honeybees (Ramsey et al., 2019) during the transmission of viral, bacterial and fungal pathogens that affect and lead to the collapse of many commercially managed apiaries, and the immune system *A. mellifera* is constantly weakening due to pathogens. The evolutionary trend of *V. destructor* shows a successful transition from its main host (*A. cerana*) to the current host (*A. mellifera*). It is considered that *A. cerana* has developed host defense mechanisms against mites (Techer et al., 2019).

The history of *V. destructor* can be traced back to 1904, when *V. jacobsoni* was first described in honey bee families *A. cerana* on the island of Java, and later spread to other parts of the world (Traynor et al., 2020). Until 2000, many scientists and beekeepers believed that *V. jacobsoni* was a mite that contributed to the death of honey bee colonies. In the same year, 2000, taxonomic work and the first microsatellites discovered previously unknown *Varroa* species and found out that *V. destructor* is able to reproduce on *A. mellifera* is also to blame for the deaths of the latter. Before Anderson and Truman described the morphological features of tick V. Destructor (2000).

Today, the mite's feeding habit is on the fat bodies and hemolymph of honey bees and the reproductive period of *V. destructor* in bee colonies undoubtedly remains the main threat to *A. mellifera* (Han, B. et al., 2024). The distribution of V. destructor is shown in detail in Figure 1.

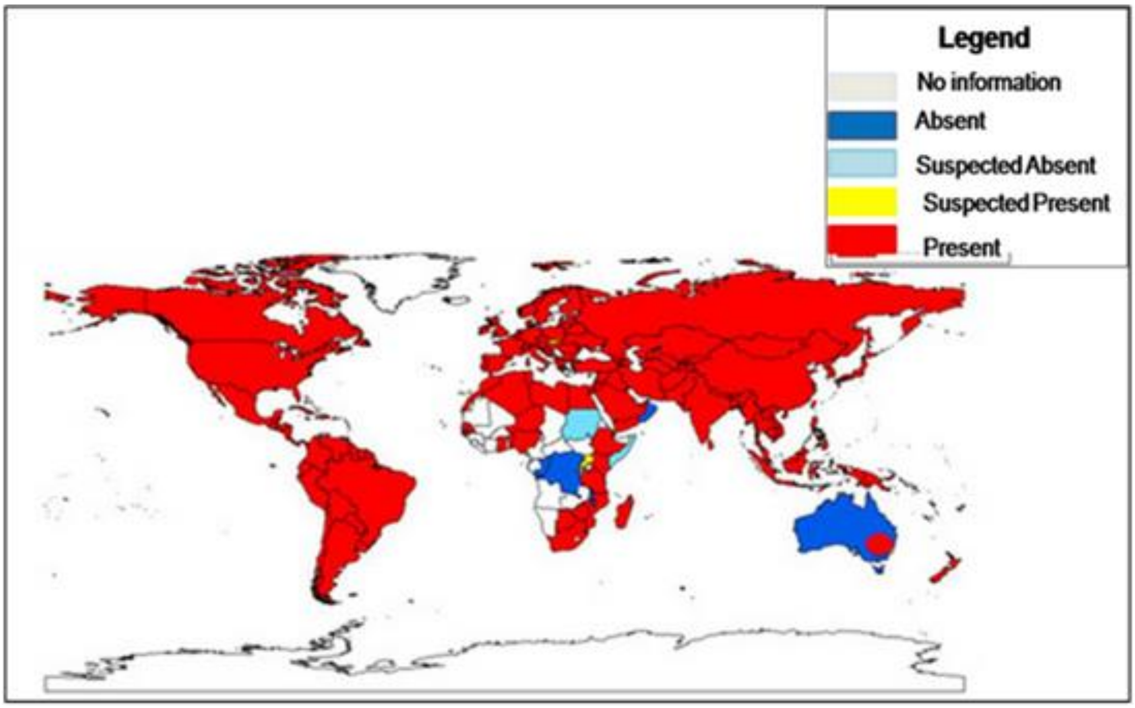

Fig. 1. **World distribution of V. Destructor. Based on CABI materials. Center for Agriculture and Bioscience International. 2024. Available online: https: /www. cabidigitallibrary.org/doi/10.1079/cabicompendium.107784 (accessed on 9 June 2024).**

Evidence suggests that the host change of *V. destructor* took about (50-100) years and became almost Global in mite distribution. In Australia, the first case of *V. destructor* was reported in June 2022 in the port of Newcastle as part of the implementation of the National *Varroa* Mite Management Program.

Rapid, widespread spread of the parasite was carried out through drift, possibly moving to new colonies, when healthy bees used (known as stealing) a resource from unhealthy ones, while strengthening weak families by adding brood from strong ones, transporting from one apiary to another without careful mite testing (Cremer, S. et al., 2007; Mondet, F. et al. 2014; Traynor, K.S. et al. 2020; Peck, D.T. et al., 2019).

The Behavioral Ecology and adaptability of *V. destructor* to its host in various climatic conditions has been complex and difficult to understand. However, several studies have described their physiology, ecology, reproduction, and host-parasite interactions. Adult females are reddish-brown or dark brown, with an oval shape about (1-1.77) mm long and (1.5–1.99) mm wide; meanwhile,adult males are yellowish, with a spherical body shape (0.75–0.98) mm long and (0.70–0.88) mm wide (Nazzi, F et al., .2016). The tick's reproductive cycle begins with oviposition and ends by the adult stage. Their life cycle includes two phases: reproductive, where adult fertile females, once they are in the cells with the brood, produce young and feed on the fat body of bee larvae and pupae, while damaging the tissues of individuals at the stage when they do not feed, while before sealing the brood, The Tick pierces the cuticle, creating a place for feeding. The reproductive success of *V. destructor* depends on their eating habits and the length of the formation period at different stages of bee development. Need the *V. destructor* in egg-laying energy requires it to extract more nutrients from the host's body, which leads to poorer conditions for adult bees (Li et al., 2019).

In this regard, the development of Natural Methods for controlling ticks through behavioral traits (stable response patterns) of honeybees is a topic for researchers. This is due to the fact that natural methods have shown a more stable and safe effect on insects than the use of synthetic or organic chemicals. The results of the study indicate the effectiveness of behavioral properties associated with the immunity of honeybees, and the potential of the latter in the fight against *V. destructor*. One of these traits – hygienic behavior – in insects originated as a social immune trait that can reduce exposure to V. in addition, this behavior of honeybees is stimulated not only by colonies affected by *V. destructor* (Aumeier et al., 2001), but also those affected by pathogens of other diseases (virosis, mycosis, bacteriosis) (Schöning et al., 2012). The predominant threats that contribute to family loss are brood diseases (Seitz, N. et al., 2015; Lee, K.V. et al., 2015). Among all these factors, the parasitic mite *V. destructor* is the central threat (Traynor et al., 2020). Recently, the behavior of honeybees in relation to affected *V. destructor* colony and their ability to remove diseased individuals are of interest to beekeepers for selecting resistant families. The results of a study of the behavior of honeybees in caring for them and their protective behavior in previous years revealed mechanisms of resistance against mites. However, the manifestation of insect behavioral traits can be influenced by many biological and environmental factors. Therefore, the proportion of damaged mites in bottom debris in nests can be used to determine the success of bees in caring for normal field conditions. Studies have shown that seven ticks selected for grooming showed significantly more damaged mites and lower damage rates after several generations of selection. The reliability of honeybee grooming behavior in selecting resistant families against *V. destructor* is poorly understood (Wagoner et al., 2020). Scientists have suggested that combining their natural immune behavior can be used as an approach to combat the effects of tick damage. Another new feature of bee colonies against *V. destructor* is their ability to slow down the reproduction of mites, which depends on the level of damage (Bubnič et al., 2024). As a result, slow growth of the tick population can be considered the main characteristic of *V. destructor*-resistant colonies. The authors also noted that keeping Queens in cages and the technique of traps using honeycombs associated with oxalic acid treatment can be considered effective treatment strategies. This approach proved to be more effective because the number of mites collected from Bee colonies that survived infection *V. destructor* (VSB), was much lower than in the control group (Mondet et al., 2020). The researchers also demonstrated that families selected for behavioral traits against *V. destructor* had significantly more damaged ticks and lower rates of invasion prevalence than those not selected for behavioral traits. Despite the introduction of many approaches to controlling the spread of mites, no effective measures to protect the health of honeybees have been fully implemented.

Many studies have focused on the biology of *V. destructor* and the history of acaricides used to control ticks (Roth, et al., 2020; Deguine et al., 2021). However, knowledge about the effects of combining the natural behavioral traits of bee colonies that are immune to ticks and the use of acaricides is negligible.

The response of honeybees to *V. destructor* is oriented on their behavior related to the immune system, which is considered hereditary. This ability can be altered by some environmental factors depending on the environment. Although environmental pollutants, poor beekeeping practices, climate change, and food stress can reduce bee populations, *V. destructor* remains the leading cause of bee loss (Oddie et al., 2018; Büchler et al. 2020).

Since *A. cerana* has acquired resistance to *V. destructor*, and it is believed that regardless of the degree of parasite damage to their current host, *A. mellifera*, individual subpopulations are still stable. It is important to note that the immune responses of honeybees associated with *V. destructor* are due to their social behavior, which is considered anti-pathogenic and can suppress deadly pathogens caused by mites.

It is believed that the survival of honey bee colonies in *V. destructor* damage is associated with natural tolerance, which can interfere with the mite's reproductive development and reduce the infectious load (Mondet et al., 2020). However, it is unclear exactly which tolerance factor reduces its number in untreated families. Hypotheses related to the immune system are questionable. It is likely that scientists will have to study each phenomenon separately.

Despite substantial knowledge of the biology of the *Varroa* mite (Locke 2016, Noël et al., 2020) beekeepers are still experiencing difficulties in the process of applying specific strategies to effectively manage it. It is noteworthy that various measures have been proposed to control the parasite – from zootechnical to organic and chemical. Some of the reported control measures include the following: physical removal of the mite (Noël et al., 2012), the hygienic behavior of bees (Noël et al., 2020) and chemical treatments (Roth et al., 2020; Deguine et al., 2021). The main organic methods of tick control are described in the literature. Instead of directly destroying the parasite using chemical methods, organic methods aim to limit the rapid reproduction of mites in the bee nest or remove them mechanically.

One of the measures is a temporary cessation of brood cultivation. Biology of the *Varroa* mite suggests that the female stays in a sealed cell with the pupa for 12 days and 5 days on a bee until she enters the next cell before sealing. The breeding cycle of the tick in this way is 17 days. Therefore, the ratio of mites on bees and brood in the nest should be approximately as follows: 30% on bees and 70% in the brood. In reality, the ratio is: 10% in bees and 90% in brood. This is because bees intensively destroy all mites that are not in sealed cells. It can be assumed that during the active period, when there is no brood, bees can more actively destroy the mite. However, mites cause more damage to bees when they can't enter the brood. Therefore, the cessation of brood cultivation cannot be prolonged. In order for all mites to leave the brood, the temporary cessation of its presence should not exceed 21 days, when the last sealed brood will appear. A situation is created when all the mites that were in the brood will pass to bees. At this time, you can apply a combined approach and treat bees with medicines, when their use in the absence of brood will be most effective. A common disadvantage of such methods is that the fruitless period weakens the strength of the family so much that under certain conditions it can die altogether (Ellis et al., 2019; Gornich M., 2024).

Another method that is proposed to be used to control varroasis involves the use of wax with reduced cells. At the beginning of using this method, the results of using wax with a reduced cell were encouraging. However, scientific studies have not shown the effectiveness of this approach. However, data analysis shows that wax with a reduced cell can still be an effective measure against *Varroa*. It is believed that on a wax with a reduced cell, the development at the pupal stage of the bee can go faster. The *Varroa* mite, which is very sensitive to such changes, may not have time to finish development, as a result, the reproduction of the parasite will be disrupted. Another hypothesis suggests that in smaller cells, the pupa is placed more tightly, and this makes it difficult for the tick to move in the cell and feed on it.

Another group of *Varroa* control methods involves mechanically removing mites from the nest by using drone wax and then removing the drone brood. On its natural host, the eastern bee *A. cerana*, the *Varroa* mite breeds exclusively on drone brood, since the development cycle of the eastern Bee is shorter and the mite does not have time to breed offspring. In families *A. mellifera* the parasite reproduces on both drone and Bee brood, but prefers drone, in which the pupa is larger and its development cycle is longer, which helps to provide the mite with sufficient food for nutrition and time for reproduction. If a drone wax is placed in the bee nest at the time of the appearance of the drone brood, and after sealing it, the brood is removed along with mites, this can prevent an outbreak of an increase in the population of the latter. The disadvantages of this method are obvious: when removing it, it is not always possible to separate the drone brood from the bee brood; bees spend too much food resources on raising drones on drone wax, the presence of which during the swarm period is simply necessary to saturate the area for reliable mating of Queens.

Another approach to mechanical tick removal involves the use of powdered sugar, talcum powder, starch or flour. The mechanism of countering the tick during such an operation is as follows. If the powder gets on the mite's feet, they disrupt the ability of the suckers and hold on to the bee, it falls to the bottom of the hive, from where it is removed by the bees. Another consequence is that bees sprinkled with powder are intensively engaged in self-cleaning (grooming), removing powder and mites from themselves at the same time. This approach can be effective, especially in combination with interrupting brood cultivation and the presence of a sealed bottom in the hive. The obvious disadvantages of the method are that 90% of the mite is in the brood, so in order for topping to be effective, it must be constantly repeated every 5 days. Also, these powders have a negative effect on eggs, open brood and unripe honey.

The next method is to use a sealed bottom, the essence of which is as follows: ticks that live in the bee nest can lose contact with the bee and fall down the Hive, and then switch back to the bees. If the bottom is bounded by a grid with a Cell (3 x 3) mm, then bees cannot touch it. Shedding mites cannot re-pass to bees. The use of a grid can help reduce the tick population in the nest, but this method cannot be used independently in mite control. However, it is effective in the diagnosis of varroasis.

The next approach is hyperthermia, or the thermal method, which is based on the fact that ticks are more sensitive to high temperatures than bees. Comfortable for the mite is the temperature close to +33°C, and for bees – + 36°C. Therefore, the mite prefers the periphery of the nest for its reproduction, where the temperature can be lower. Only after the appearance of varroasis was the method of mite control used using thermal chambers – the bees were shaken into a special cassette, then placed in a container where the temperature (+46 – 48)°C was maintained for a certain time for 12-15 minutes. Mites in such conditions died, and bees survived. The method was time-consuming and complex, but quite effective. Over time, it turned out that prolonged use of the method can lead to the appearance of heat-resistant mites, because the method ceases to be effective.

Another approach is the separation of colonies, which consists in creating a sufficient number of new ones to replace those who died. There are ways to create new families with a small extent of invasion. These are swarms and infertile nuclei (layers). If you create a new family only from flying bees, then for at least two years such a family can have a low extent of invasion, and be productive. But such a strategy can be quite risky. However, when a part of the apiary dies from varroasis, only division can restore the number of bee colonies. (Gornich M., 2024).

Environmentally friendly methods are actively used due to the resistance of V. destructor to mild acaricides (thymol, formic and oxalic acids) and the deadly effects of aggressive acaricides (amitraz, fluvalinate and flumethrin) on honeybees (Jack et al., 2021) although mechanical methods (physical removal of ticks, etc.) are less harmful to insects, they have many limitations, in particular: increased labor for beekeepers, sensitivity to fluctuations in ambient temperature, and minimal differences between lethal concentrations for mites and honeybees (Noël et al., 2020).

Organic methods of controlling *V. destructor* based on behavioral traits associated with the immune system have been actively used. The most important area of such work is the breeding of lines and populations of bees that are resistant to varroasis. Varroaresistance is the suppression of the reproduction of a mite by bees or the coexistence of bees with a tick so that it does not cause noticeable damage to the latter. The basis of such breeding is the genetics of bees. The goal of such breeding work should be to keep the extent of the invasion constantly low and not increase.

Some of these measures have little proven effectiveness, and they can be harmful to bees. Thus, Rosenkranz et al. (2010) reported that the use of aggressive chemicals (acaricides) to reduce *V. destructor* populations is only temporarily effective precisely because of the emergence of rapidly developing resistant tick individuals. Also Warner et al. (2024) reported the use of thymol, oxalic and formic acids, beta-acids, formamidine, and fluvalinate to control the spread of *V. destructor* was not resistant due to the appearance of resistance in ticks to active substances and the risk to the health of honeybees with an increase in their concentration. The use of chemicals to control the spread of *V. destructor* has shown that the use of synthetic, organic and inorganic chemicals in low doses may be safer for bees. However, their effectiveness is still unknown due to the lack of experimental evidence (Warner et al., 2024). Another study demonstrated that physical tick removal is limited to increasing labor for beekeepers. The ineffectiveness of chemical control measures and the lack of desire to physically remove mites did not leave an opportunity for pest control.

Attempts to create bees that can inhibit the development of the mite or co-exist with it have partially yielded satisfactory results. In particular, mite-resistant bee lines have been bred in the United States. These are the so-called bees with *Varroa* sensitive hygienic behavior (VSH-bees), the essence of which is that bees sense the presence of a tick in cells with sealed brood, open such cells and remove pupae infected with the mite along with the parasite. In this case, the mite's reproductive cycle is interrupted and it dies, even if it remains in the nest. If the cell was printed by mistake, the bees do not remove the pupa, but re-seal it. This behavior of bees is known as re-printing the brood.

There are families where bees are intensively engaged in grooming (cleaning their bodies from mites). At the same time, they bite (do not sting!) mites, separate their legs or damage their shell. Such mites can no longer parasitize bees and are removed from the nest. To assess how effective this behavior of bees is, you need a sealed or sticky bottom of the hive to assess the scree of ticks for two days. Then the crumbling mites need to be examined under a microscope and identify the number of crippled ones. If more than a third (35%) of the crumbled ticks are damaged, then such a family can be considered varroaresistant. The beekeeper has two options for breeding resistant to *Varroa* mites bees: write out queens of certified lines or breed such insects yourself.

Breeding varroaresistant bees gives the beekeeper an additional advantage: in this way, he gets rid of the threat of bee damage by a number of other pathogens of bacterial, viral and fungal diseases. Breeding resistant to *Varroa* mites bees is not an easy task, since the mating system of queens creates risks of losing the varroaresistance trait in subsequent generations of queens. But in the process of breeding bees resistant to ticks, there were also disadvantages. It turns out that parasite-resistant bees in one area, once transported to another, may cease to be so. For example, queens bred in Hawaii, when introduced to continental America, no longer showed signs of resistance. That is, the sign of varroaresistness is most fully manifested in the local population of bees and ticks. It is also difficult to breed such bees in one, separate apiary. The work can give a positive result when breeding is performed for all bee colonies of the local population (Gornich M., 2024).

Mechanical and organic methods remain reliable, environmentally friendly and sustainable. Undoubtedly, immune-related behavioral traits of honeybees can provide resistance to mites. Therefore, to limit the spread of the parasite, beekeepers should choose genetically resistant bee colonies created without human intervention. Beekeepers have adopted cultural methods related to the social immunity of honey bees to combat the effects of mite parasitism (Jack et al., 2021; Mondet et al., 2020). For example, some owners of industrial apiaries choose Bee seeds that are resistant to V. destructor based on their active hygiene behavior (ability to remove dead brood, identify and remove brood affected by *Varroa*, grooming), (Traynor et al. 2020; Noël et al., 2020; Warner et al., 2024). The population dynamics of *V. destructor* and honeybees show the importance of a break from brood to adult bees. A large time lag in the development of adult bees can disrupt population dynamics and contribute to family death. In this case, a shorter time interval from brood to adult bees will prevent the development of *V. destructor*, and seven я I'll stay strong and healthy. It is also important to note that the *Varroa* mite can die due to seasonal changes (Messan, K., et al., 2020).

Although beekeepers and scientists have developed and tested *V. destructor* control chemicals, they are still not reliable. Chemical controls based on thymol, oxalic and formic acids, formamidine and fluvalinate are not stable. For example, several researchers have reported high mortality in honeybees when using solid acaricides (amitraz, fluvalinate, and flumethrin), even at the recommended doses (Kayode et al., 2014). Although bee mortality is also affected by the outside temperature (below +9 °C), significantly higher mortality of adult bees can be attributed to the methods of using the drug. For example, when using the seepage method, a higher mortality rate of adult bees was recorded than the evaporation method (Coffey et al., 2016). Since mites transmit infectious pathogens, beekeepers believe that the use of chemicals may be the most effective control measure. Mild acaricides (thymol, oxalic and formic acids) are known to be less toxic to adult bees. After long-term evaluation of mild chemicals, they were found to be ineffective due to the rapid development of tick resistance (Truong et al., 2022). However, the rejection of formic, oxalic acids, amitraz, fluvalinate, and other acaricides that control *V. destructor*, especially in summer, does not negate their use and effectiveness (Wu et al., 2024)

Due to the risks associated with synthetic chemical treatments, beekeepers are rapidly shifting their focus to organic chemicals with proven acaricidal efficacy characteristics. Control of *V. destructor* is difficult due to its resistance to widely used acaricides and the lack of recommended methods. However, research continues. Integrating multiple pest control tools and techniques can produce better results than a single strategy (Cremer et al., 2007, Evans et al., 2011).

Sociality in honeybees allowed them to gain properties of social immunity against their enemies, including кліщем *Varroa*. The succession of *V. destructor*-related immune traits prompted beekeepers to evaluate and maintain families with persistent behavioral traits. One of these behavioral signs of honeybees is hygienic behavior.

Many animals exhibit hygienic behavior for a specific purpose. In honeybees, this ability consists of keeping the nest clean, removing dead or diseased brood from the cells, and removing unwanted particles from the body. The hygienic behavior of honeybees was described in the 1930s, when researchers discovered that resistant colonies against American foulbrood rot (AFB) removed diseased larvae (Spivak et al., 2009). After this period, the study of the hygienic behavior of honeybees became much more active. The researchers described hygienic behavior and provided evidence that AFB resistance is the ability to detect and remove diseased brood before the pathogen reaches the infectious stage of diseased larvae. This reaction of bees is considered common and applicable to all honey families. More recent studies have shown that adult bees from some colonies removed ascospherosis-infected larvae from their cells within 24 hours, and this made them resistant to the disease (Danka et al., 2013).

Hygiene responses in bee colonies can be complex and sometimes difficult to understand or analyze. The two most important methods, freezing or pinning, are commonly used in analyses to determine the hygienic behavior of honey bee colonies. Similarly, hygienic behavior was used to evaluate honey bee families for resistance to *V. destructor*. Thus, removal of mite-infested brood and removal of frozen larvae are positively correlated (r = 0.74). However, Danka et al. (2013) reported a weak correlation. Further research suggested that the variation may be related to individual hygiene behavior in relation to a particular pathogen, rather than just general hygiene. This behavioral specificity led to another form of hygienic behavior known as VSH, whose evolution in honeybees contributed to the selection of resistant insects against *V. destructor*.

Discussion. Discussions among scientists have led to questions such as “what method or strategy can be an effective measure to control *V. destructor*?”. Summarizing the above, we can distinguish four possible ways to deal with a mite *Varroa*:

* Practice safe seven-pit management (good beekeeping practice). In all apiaries, management is a fundamental strategy for successful beekeeping. Management tools and practices are complex because they depend on both individuals and the environment. However, some special rules are implemented in most apiaries. Good management practices at different times of the year are crucial for controlling honeybee ectoparasites. For example, family productivity can be improved by using poor management techniques that can delay *V. destructor* reproduction during spring and summer. It is important to understand the biology of *V. destructor* and assess the level of damage each season of the year to ensure the effectiveness of treatment and prevent possible negative effects of chemical therapy on bees. Therefore, it is necessary to implement a strategic management plan for V. destructor and distribute it to beekeepers and scientists. Resolving this situation is not a personal matter for the beekeeper. Rather, it is a daily struggle to limit the spread of the parasite to the entire beekeeping community. In addition to these highlights, key management practices were highlighted to prevent high levels of *V. destructor* damage in seven honeybees at the beginning of the honey harvest season (Rudenko E. V. et al., 2022 Giacobino, A., et al., 2016). The main strategy is to ensure that beekeepers check and report all possible pathologies in families in a timely manner, and apply appropriate control measures to maintain an indicator of the extent of invasion *V. destructor* is below 2%.

* One possible way to preserve the immune properties of honeybees is through selective breeding. The complexity of the" mating " behavior of insects and the difficulties that arise when choosing breeding sites have made it difficult for beekeepers to preserve breeding lines for many generations. For this purpose, suitable breeding sites are proposed to support the genetic resources of honeybees. Recently, Akongte et al. (2024) demonstrated the ability to breed and maintain honey bee families at isolated mating stations.

* To successfully control the parasite, it is necessary to combine several approaches to increase the effectiveness of each of them. As for *V. destructor*, breeding of resistant bee lines is developing rapidly, but chemical treatments should not be forgotten. The ideal situation is to combine stable bee colonies with the recommended mild chemical treatment (thymol and oxalic acid). This can weaken *V. destructor* and

improve the effectiveness of families in slowing down tick reproduction. It is also recommended to apply a mild chemical treatment at an early stage of the honey collection season after selecting resistant strains before the mites multiply rapidly. Mild chemical treatment is expected to interfere with *V. destructor* fertility and create conditions under which resistant honeybee strains can completely neutralize the rest of the population.

Conclusions. Despite the variety of available alternatives for managing the amount of *V. destructor* in bee colonies, a better solution has not yet been made. Based on basic and Applied Research, control measures using mild chemicals (oxalic acid and fluvalinate) were developed and proposed. Today, the combination of zootechnical, mechanical, organic and chemical measures to control the extent of varroasis invasion has confirmed the importance of adopting comprehensive approaches. Researchers should take into account data on geographical location, ecology, damage rates, health impacts of honeybees, and existing management strategies. As a result, organic methods based on the genetic selection of honeybees with immune traits to *V. destructor* and high heredity can be reliable.

References

Anderson, D. L., Trueman, J. (2000) Varroa jacobsoni (Acari: Varroidae) is more than one species. *Experimental & Applied Acarology,* 24, 165–189. https://doi.org/10.1023/A:1006456720416

Aumeier, P., Rosenkranz, P. (2001) Scent or movement of Varroa destructor mites does not elicit hygienic behavior by Africanized and Carniolan honey bees. *Apidologie* 32, 253–263. https://doi.org/10.1051/apido:2001127

Bubnič, J., Prešern, J., Pietropaoli, M., Cersini, A., Moškrič, A., Formato, G., Manara, V., Škerl, M. (2024) Integrated pest management strategies to control Varroa mites and their effects on viral loads in honey bee colonies. *Insects,* 15, 115. https://doi.org/10.3390/insects15020115

Büchler, R., Kovačić, M., Buchegger, M.; Puškadija, Z., Hoppe, A., Brascamp, E. W. (2020) Evaluation of traits for the selection of Apis mellifera for resistance against Varroa destructor. *Insects*, 11, 618. https://doi.org/10.3390/insects11090618

Deguine, J. P., Aubertot, J. N., Flor, R. J., Lescourret, F., Wyckhuys, K.A., Ratnadass, A. (2021). Integrated pest management: Good intentions, hard realities. A review. *Agronomy for Sustainable Developmen*, 41, 38. https://doi.org/10.1007/s13593-021-00689-w

CAB International. (2024) Center for Agriculture and Bioscience. Available online: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.107784

Coffey, M. F., Breen, J. (2016) The efficacy and tolerability of Api-Bioal as a winter varroacide in a cool temperate climate. *Journal of Apicultural Research*, 55, 65–73. https://doi.org/10.1080/00218839.2016.1200866

Cremer, S., Armitage, S.A., Schmid-Hempel, P. (2007) Social immunity. *Current Biology*, 17, R693–R702. https://doi.org/10.1016/j.cub.2007.06.008.

Danka, R. G., Harris, J. W., Villa, J. D., Dodds, G. E. (2013) Varying congruence of hygienic responses to Varroa destructor and freeze-killed brood among different types of honeybees. *Apidologie,* 44, 447–457. https://doi.org/10.1007/s 13592-013-0195-8

Dietemann, V.; Pflugfelder, J.; Anderson, D.; Charrière, J.-D.; Chejanovsky, N.; Dainat, B.; de Miranda, J.; Delaplane, K.; Dillier, F.-X.; Fuch, S.; et al. (2012) Varroa destructor: Research avenues towards sustainable control. *Journal of Apicultural Research*, 51, 125–132. https://doi.org/10.3896/IBRA.1.51.1.15

Ellis, J. D., Zettel-Nalen, C. M. (2019) Varroa, Varroa Destructor. University of Florida. Available online: https://entnemdept. ufl.edu/creatures/misc/bees /varroa mite.htm

Evans, J. D.; Schwarz, R. S. (2011) Bees brought to their knees: Microbes affecting honey bee health. *Trends Microbiology*, 19, 614–620. https://doi.org/10.1016/j.tim.2011.09.003

Giacobino, A., Molineri, A., Cognolo, N. B., Merke, J., Orellano, E.; Bertozi, E., Masciangelo, G., Pietronave, H., Pacini, A., Salto, C. et al. (2016) Key management practices to prevent high infestation levels of V. destructor in honey bee colonies at the beginning of the honey yield season. *Preventive Veterinary Medicine*, 131, 95–102. https://doi.org/10.1016/j.prevetmed.2016.07.013

Han, B., Wu, J., Wei, Q., Liu, F., Cui, L., Rueppell, O., Xu, S. (2024) Life history stage determines the diet of ecto-parasitic mites on their honey bee hosts. *Nature Communications*, 15, 725. https://doi.org/10.1038/s41467-024-44915-x

Hornich M. (2024) Zootekhnichni i orhanichni metody kontroliu klishcha varroa https://gornich.com.ua

Kayode, L., Lizette, D., Johnson, R.M., Siegfried, B. D., Ellis, M. D. (2014) Effect of amitraz on queen honey bee egg and brood development. *Mellifera*, 14, 33–40.

Kirrane, M. J., de Guzman, L. I., Holloway, B., Frake, A. M.; Rinderer, T. E., Whelan, P. M. (2014) Phenotypic and genetic analyses of the varroa sensitive hygienic trait in Russian honey bee (Hymenoptera: Apidae) colonies. *PLoS ONE*, 10, e0116672. https://doi.org/10.1371/journal.pone.0116672

Lee, K. V., Steinhauer, N., Rennich, K., Wilson, M. E., Tarpy, D. R., Caron, D. M., Rose, R., Delaplane, K. S.; Baylis, K.; Lengerich, E. J.; et al. (2015) A national survey of managed honey bee 2013–2014 annual colony losses in the USA. *Apidologie*, 46, 292–305. https://doi.org/10.1007/s13592-015-0356-z

Li, A. Y., Cook, S. C., Sonenshine, D. E., Posada-Florez, F., Noble, N., Mowery, J., Gulbronson, C. J., Bauchan, G. R. (2019) Insights into the feeding behaviors and biomechanics of Varroa destructor mites on honey bee pupae using electropenetrography and histology. *Journal of Insect Physiology*, 119, 103950. https://doi.org/10.1016/j.jinsphys.2019.103950

Locke, B. (2016) Natural Varroa mite-surviving Apis mellifera honeybee populations. *Apidologie*, 47, 467–482. https://doi.org/10.1007/s13592-015-0412-8

Meisch, C. (1986) Varroa milbe. Geschichte der Ausbreitung, Portrait und Biologie. In *Livre d'or du Centenaire 1886–1986*; Fédération des unions d'apiculteurs du grand-duché de Luxembourg: Luxembourg, pp. 174–177. https://doi.org/10.3390/agriculture14112094

Messan, K., Messan, M. R., Chan, J., DeGrandi-Hoffman, G., Kang, Y. (2020) Population dynamics of Varroa mite and honey bee: Effects of parasitism with age and seasonality. *Ecole Schools*, 440, 109359. https://doi.org/10.48550/arXiv.2003.12089

Mondet, F.; de Miranda, J. R.; Kretzschmar, A.; Le Conte, Y.; Mercer, A.R. (2014) On the front line: Quantitative virus dynamics in honeybee (Apis mellifera L.) colonies along a new expansion front of the parasite Varroa destructor. *PLoS Pathogens*, 10, https://doi.org/10.1371/journal.ppat.1004323.

Mondet, F., Beaurepaire, A., McAfee, A., Locke, B., Alaux, C., Blanchard, S., Danka, B., Le Conte, Y. (2020) Honey bee survival mechanisms against the parasite Varroa destructor. A systematic review of phenotypic and genomic research efforts. *International Journal for Parasitology*, 50, 433–447. https://doi.org/10.1016/j.ijpara.2020.03.005

Nazzi, F., Le Contr, Y. (2016) Ecology of Varroa destructor. The major ectoparasite of the western honey bee, Apis mellifera. *The Annual Review of Entomology*, 61, 417–432. https://doi.org/10.1146/annurev-ento-010715-023731

Noël, A., Le Conte, Y., Mondet, F. (2020) Varroa destructor. How does it harm Apis mellifera honey bees and what can be done about it? *Emerging Topics in Life Sciences*, 4, 45–57. https://doi.org/10.1042/ETLS20190125

Oddie, M., Büchler, R., Dahle, B., Kovacic, M., Le Conte, Y., Locke, B.; de Miranda, J.R., Mondet, F., Neumann, P. (2018) Rapid parallel evolution overcomes global honey bee parasite. *International Journal of Scientific Reports*, 8, 7704. https://doi.org/10.1038/s41598-018-26001-7

Oddie, M. A. Y., Dahle, B., Neumann, P. (2018) Reduced postcapping period in honey bees surviving Varroa destructor by means of natural selection. *Insects*, 9, 149. https://doi.org/10.3390/insects9040149

Peck, D. T., Seeley, T. D. (2019) Mite bombs or robber lures? The roles of drifting and robbing in Varroa destructor transmission from collapsing honey bee colonies to their neighbors. *PLoS ONE*, 14, https://doi.org/10.1371/journal.pone.021839

Ramsey, S. D.; Ochoa, R.; Bauchan, G.; Gulbronson, C.; Mowery, J.D.; Cohen, A.; Lim, D.; Joklik, J.; Cicero, J. M.; Ellis, J. D. (2019) Varroa destructor feeds primarily on the fat body tissue and not hemolymph. *Proceedings of the National Academy of Sciences*, 116, 1796–1801. https://doi.org/10.1073/pnas.1818371116

Rosenkranz, P., Aumeier, P., Ziegelmann, B. (2010) Biology and control of Varroa destructor. Journal of Invertebrate *Pathology*, 103, S96–S119. https://doi.org/10.1016/j.jip.2009.07.016

Roth, M. A., Wilson, J. M., Tignor, K.R., Gross, A. D. (2020) Biology and management of Varroa destructor (Mesostigmata: Varroidae) in Apis mellifera (Hymenoptera: Apidae) colonies. *Journal of Integrated Pest Management*, 11, 1. https://doi.org/10.1093/jipm/pmz036

Rudenko Ye. V. Maslii I. H (2022) Nalezhna bdzholiarska praktyka v tekhnolohii utrymannia medonosnykh bdzhil. *Naukovo-tekhnichnyi biuleten Instytutu tvarynnytstva NAAN* https://doi.org/10.32900/2312-8402-2022-128-180-188

Schöning, C., Gisder, S., Geiselhardt, S., Kretschmann, I., Bienefeld, K.; Hilker, M.; Genersch, E. (2012) Evidence for damage-dependent hygienic behavior towards Varroa destructor-parasitised broods in the western honey bee, Apis mellifera. *Journal of Experimental Biology*, 215, 264–271. https://doi.org/10.1242/jeb.062562

Seitz, N., Traynor, K. S., Steinhauer, N., Rennich, K., Wilson, M. E., Ellis, J. D., Rose, R., Tarpy, D. R., Sangili, R. R., Caron, D. M. et al. (2015) A national survey of managed honey bee 2014–2015 annual colony losses in the USA. *Journal of Apicultural Research*, 54, 292–302. https://doi.org/10.1080/00218839.2016.1153294

Spivak, M., Reuter, G. S., Lee, K., Ranum, B. (2009) The future of the MN hygienic stock of bees is in good hands! *American Bee Journal*, 149, 965–967.

Techer, M. A., Rane, R. V., Grau, M. L., Roberts, J. M. K., Sullivan, S. T., Liachko, I., Childers, A. K., Evans, J. D., Mikheyev, A. S. (2019) Divergent selection following speciation in two ectoparasitic honey bee mites. *Communications Biology*, 2, 357. https://doi.org/10.1101/512988

Traynor, K. S., Mondet, F., De Miranda, J. R., Techer, M., Kowallik, V., Oddie, M. A., Chantawannakul, P., Mcafee, A. (2020) Varroa destructor: A complex parasite, crippling honey bees worldwide. *Trends in Parasitology*, 36, 592–606. https://doi.org/10.1016/j.pt.2020.04.004.

Truong, A. T., Yoo, M. S., Yun, B. R., Kang, J. E., Noh, J., Hwang, T. J., Seo, S. K., Yoon, S. S., Cho, Y. S. (2022) Prevalence and pathogen detection of Varroa and Tropilaelaps mites in Apis mellifera (Hymenoptera, Apidae) apiaries in South Korea. *Journal of Apicultural Research*, 62, 804–812. https://doi.org/10.1080/00218839.2021.2013425

Wagoner, K. M., Millar, J. G., Schal, C., Rueppell, O. (2020) Cuticular pheromones stimulate hygienic behavior in the honey bee (Apis mellifera). *International Journal of Scientific Reports*, 10, 7132. https://doi.org/10.1038/s41598-020-64144-8

Warner, S., Pokhrel, L. R., Akula, S. M., Ubah, C. S., Richards, S. L., Jensen, H., Kearney, G.D. (2024) A scoping review on the effects of Varroa mite (Varroa destructor) on global honey bee decline. *Science of The Total Environment*, 906, 167492. https://doi.org/10.1016/j.scitotenv.2023.167492

Wu, J.; Liu, F.; Sun, J.; Wei, Q.; Kang, W.; Wang, F.; Zhang, C.; Zhao, M.; Xu, S.; Han, B. (2024) Toxic effects of acaricide fenazaquin on development, hemolymph metabolome, and gut microbiome of honeybee (Apis mellifera) larvae. *Chemosphere*, 358, 142207. https://doi.org/10.1016/j.chemosphere.2024.142207