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REVIEW PAPER ON *VARROA* INFESTATION, DETECTION AND PREVENTION IN BEEHIVES

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Abstract: *The widely recognized insect known as the honey bee (Apis mellifera) has a beneficial impact on both the environment and human life, making it important to protect them not just for ecological reasons but also for the economic and social advancement of countryside regions. Their existence is so essential that the recent decrease in honey bee hives has caused a growing interest in them. One of the reasons for bees' decline in population is infestation with a parasite known as Varroa destructor. In order to effectively treat the V. destructor infestation, it is critical to monitor the amount of infestation in hives. While there is at present no specific sensor for this job, continuous and discrete monitoring of hive infection levels as well as other critical bee colony characteristics, such as temperature and humidity, is wanted. The use of chemicals by apiarists is a method of controlling the infestation that is the most common strategy. Substitute tactics include the use of organic compounds, organic products like essential oils, and biotechnological techniques like mite trapping. Therefore, successful therapy and preventing harsh chemical use can reduce bee mortality and economic losses.*

Key words: *Smart apiculture, Varroa, Honey bee, Monitoring.*

1. Introduction and Overview

What is Varroa? Simply said, *Varroa destructor* is a mite, a parasite that attaches itself to the bee, like a tick on a human being. The most dangerous pests to adult and larvae bees, *Apis mellifera* are Varroa mites. Adult bee body, weight, life expectancy, and resistance to infections are all decreased as a result of mites feeding on bees (Jong et al., 1982; Martin S. J., 1994; Büchler, 2015; Roberts et al., 2017). Varroa mites are from 1.5mm to 2mm wide and one mite approximately weights 0.453mg while one bee weighs around 110mg. Adult female mites spread via phoresy by latching to worker bees and drones. The mites enter into brood cells occupied by mature bee larvae before worker bees seal comb cells with wax, where they ultimately consume the fat tissue and hemolymph of the host larvae (McMenamin and Genersch, 2015; Wallner, 1999). Left unattended, infected honey bee colonies typically die within a year if the mite population grows unnoticed and untreated (Büchler, 2015). While there are several causes that might lead to colony death, Varroa infection (Roberts et al., 2017) and the spread of a wide variety related to bee viruses are often deemed to be the most significant (McMenamin and Genersch, 2015). There is a paradox in the chemical treatment for varroa mites. It is necessary to apply poisonous substances to kill mites, however, these chemicals can also have negative and lethal effects on bees and entire colonies. In order to avoid the accumulation of chemical leftovers and their side effects in bees, honey, and wax while also preventing the development of acaricide resistance, pesticides must be used at their lowest effective dose (Wallner, 1999; Ruijter, 1994). Acaricides with lower leftovers and greater mite monitoring could help decrease significantly the quantity of harmful active ingredients used each season. Thus, we examine studies on mite monitoring advancements, detection, and prevention systems.

2. Early detection of Varroa mites in a beehive as a means of prevention

Szczurek et al. (2020) describes an innovative method that makes use of E-nose technology. Once the infestation affects the chemical makeup of the air inside a hive, it is used to detect varroa. The moment of detection is what determines if this method is effective.

Utilizing Mel or fast Fourier transform (FFT) spectrograms in sound monitoring systems is another effective method for identifying Varroa mites. In particular, threats from the outside, colony anxiety, swarming, and queen loss can be distinguished by using frequency-amplitude over time representations in combination with Support Vector Machine (SVM) and neural network classifiers (Nolasco et al., 2019). Colony collapse can be used as a signal to confirm the presence of the Varroa mite.

Currently, basic field and lab diagnostic techniques are accessible for determining the level of varroa mite contamination throughout complete honey bee colonies. Throughout decades, beekeepers have been measuring the effectiveness of an acaricide treatment by quantifying the dead mites that fall off the bees and brood frames into the bottom board of the hive (Ritter, 1981; Gregorc and Jelenc, 1996). A good correlation exists between the quantity of these dead mites detected in a hive's waste and the mite populations now infesting the colony atop (Liebig et al., 1984). In fact, researchers looked at the relationship between the total amount of mites in honey bee colonies and natural mite mortality. They discovered that the daily varroa mite deaths found on hive bottom planks can be multiplied by 20–40 to estimate the varroa mite numbers in colonies including brood (Harris, 2019). Control is necessary after completing mite assessments and once varroa infestations have risen to 3 mites per 100 bees within a colony (Harris, 2019). The quantity, location, management, and additional stress factors of the hive will all affect the treatment threshold values (Mattila and Otis, 2000). To determine the extent of mite contamination before and after acaricidal treatment and seasonal shifts in the number of natural mite populations, it is essential to preserve data records of the natural mite drop rates inside a colony (Martin S., 1998). Since varroa mite concentrations under 100 mites per colony are unable to be identified by looking at samples of adult bees or brood (Ritter, 1984), bottom plank counts are particularly helpful for calculating overall varroa mites per colony and daily mite deaths (Branco et al., 2006). Nevertheless, bottom board mite count-based mite sampling techniques are time-consuming, more expensive, and may require many days or weeks to determine an appropriate degree of colony infection. The level of mite removal by bees for hygienic purposes may also affect varroa mite numbers (Spivak and Reuter, 2001).

The "sugar shake" is an easy non-destructive technique for collecting varroa mite samples from adult honey bee bodies. The only step in this method is to sprinkle sugar on live bees' body parts. The tarsal pads of varroa mites will quickly become clogged by the powdered sugar, losing stickiness, and becoming permanently detached from host bees (Fakhimzadeh et al., 2011). For mite counting purposes, the sugar shake approach eliminates 77% to 91% of the mites (Fakhimzadeh, 2001; Aliano and Ellis, 2005). The sugar shake technique can retrieve 82% of varroa mites even in heavily plagued colonies (Macedo et al., 2002). Numbers of mites dislodged from adult bees taken from a single brood frame can be used to extrapolate the size of mite populations in the entire colony. Simply counting dislodged mites from more captured bees will result in precise projections of colony infestation (Lee et al., 2010). Therefore, the "sugar shake" method is a quick and accurate way for beekeepers to determine how many varroa mites are present on adult worker bees, drones, and even in entire colony (Macedo et al., 2002; Dietemann et al., 2013). When assessing various mite controls, sugar shake is another helpful sampling procedure (Gregorc et al., 2018). The sugar shake procedure has a few limitations that should be taken into account. While using the sugar shake method, there are a few things to keep in mind. Variations in the size of the honey bee population and environmental factors can affect how well the powder shake method extracts varroa mites from adult host bees. In a warm, moist climate (i.e., 32 °C and 76 RH), the sugar shake method's average effectiveness to remove varroa mites from adult honey bees is only about 66%, which is lower than the 94% achieved in cooler and dryer conditions (i.e., 26 °C and 71% RH) (Gregorc et al., 2017). Several sugar blends work better than others in terms of varroa removal due to differences in sugar quality. For example, a smooth dusting of pure powdered sugar removes 70-80% of varroa mites, which is significantly more than the 50% varroa drop attained using a mixture of powdered sugar and cornstarch. As a result, the efficacy of sugar shakes to eliminate mites may be influenced by the quality of the sugar combined with high humidity (Fakhimzadeh et al., 2011). It's possible that higher temperatures and humidity levels cause granules to coagulate, making sugar coarser and reducing the likelihood of tarsal clogging. Dusting honey bees with sugar is generally regarded as a secure mechanical technique for identifying colony infestations and, in some circumstances, can be used to lessen varroa mite infestation in field colonies (Gregorc et al., 2018).

The application of washing kits, usually homemade, with water or alcohol (70%) functioning as both the washing and collection fluid is a method equivalent to preventing mites from host bees (Toufailia et al., 2014). In hives absence of brood, accurate counts of varroa mites on adults can be made for research or practical beekeeping purposes using either the sugar shake method, water wash, or alcohol wash. About 300 bees are lost when employing an alcohol wash, but there is no apparent effect on the health and productivity of the colony. Alcohol washes, nonetheless will eliminate both mites and the few bees handpicked for sampling. To ensure colony survival and productivity, precise assessments of colony infection acquired with this diagnostic test are essential (Medina and Martin, 1999). Treatments of miticides or alternative therapies may be necessary based on a determined number of varroa mites discovered by sugar shake or alcohol wash. As a result, both approaches can be used to evaluate the efficacy of earlier control procedures. For beekeepers, varroa mite rates between 3 and 5 percent are acceptable. Varroa mite control must be carried out right away when mite counts are greater than 5% (Lindberg et al., 2000; Imdorf et al., 1999). In the United States, a comparable wide range of economic thresholds for varroa mite populations in colonies have been established at values between 5 and 12 percent, while most beekeepers prefer to utilize the lower 5 percent (Harris, 2019). By examining the mite weighs on adult and pupal bees in addition to counting the dead varroa mites within a colony, accurate projections of the size of the varroa mite population can be made. The ability of varroa females reproduction in worker nest cells is a major factor in the dynamics of the varroa mite population (Giacomelli et al., 2016; Bogdanov et al., 1998). Additionally, by combining samples from adult bees and brood, as well as comparing those results with the amount of mites eliminated through chemical treatment, the extent of the mite population can be approximated (Nanetti and Stradi, 1997).

The technology of cloud computing and low-power Wireless Sensor Network (WSN) is in use to monitor the presence of bees exhibiting stress behavior, which includes the presence of the Varroa mite (Kontogiannis, 2019; Edwards Murphy et al., 2015; Bellos et al., 2021). One of this study's goals is to utilize WSN technology to spot a beehive colony and gather vital data regarding the activities of the surroundings, within a beehive, and regarding the bees' health. However, as stated by (Kontogiannis, 2019), Varroa mite discovery employing sensors (temperature, humidity, noise level, and gas sensors) may contain numerous false-positive cases since other phenomena like swarming, queen loss, or even starvation may generate Colony Collapse Disorder (CCD) that are mistaken for those caused by the mite.

Var-Gor device is an appealing option for the prompt identification of Varroa mites and its early treatment because of its green and sustainable nature, reliable results, and cutting-edge design (Sevin et al., 2021). Particularly, the Var-Gor technology identifies the mite using picture capture, pattern matching, color categorization, and segmentation filters when an infected bee with varroa enters an unaffected hive. Additionally, the beekeeper's phone receives an alert with a warning.

The researchers from (Mrozek et al., 2021) created an experimental system for real-time bee monitoring utilizing cameras and deep learning techniques. Their idea is based on the Raspberry Pi (RPi) single-board computer platform and intends to analyze bee video streams in order to find varroosis. Additionally, they used two Convolutional Neural Network (CNN) models in two different detection procedures, one for bees and another for Varroa. However, because the camera is outside the hive, it is difficult to detect mites before they become a problem. In the event of an infection, the images of the sick bees are sent to the cloud-based data center for additional analysis, archiving, updating the CNN models, and notifying the appropriate personnel. As the writers of this work suggest an offline system method, it is challenging to apply detection to a solitary RPi device inside the device due to the usage of two different CNN models. Additionally, a CNN trained network that accurately detects bees, for instance, the one the authors of this paper suggest, can be used to provide methods for image processing like edge detection Hough transformations, region labeling, and color masking that correctly recognize the mite on the identified bees.

By manually separating infected from non-infected bees and using a laser to kill the infected ones, the authors of (Chazette et al., 2016) offer a camera-based method of CNN-trained networks. The disadvantage of this method as it is now given is the use of single bee image labels and classifications. Due to the high numbers of bees on each frame, this can perform well at detecting individual bees on the beehive entrance openings or a white backdrop but substantially worse at detecting bees inside the frames, where the mites live. This research suggests using frame images where hand bee labeling and image localization are done before CNN training to solve this issue. Image segmentation and manual region of interest (ROI) identification can produce noticeably better results because certain areas of the image don't contain any information.

A solution to identifying Varroa mite from a small number of poor-quality photos is what the researchers at (Kaur et al., 2022) are attempting to deliver. To distinguish between diseased and healthy bees from normal bee photos, the suggested model incorporates the image enhancement approach CLAHE, the data augmentation method DCGAN, and the optimal classification method CNN. CLAHE stands for contrast limited adaptive histogram equalization, while DCGAN stands for deep convolutional generative adversarial networks. The findings show that the CLAHE approach enhances sharpness and has a good impact on CNN efficiency. Additionally, in the infection recognition scenario, the DCGAN augmentation method showed more promising outcomes than the traditional ones. To conclude, it seems that this vision-based approach is more effective and appropriate for locating Varroa mites on bees.

Furthermore, the researchers of (Bilik et al., 2021) tested the effectiveness of cutting-edge object detectors utilizing datasets labeled with information on sick bees and varroa mites. They next experimented with CNN algorithms to accomplish unhealthy bee detection, including YOLOv5 (Redmon et al., 2016) and SSD (Liu et al., 2016). According to the authors' CNN assessment utilizing F1-score findings, SSD varroa mite identification scored above 70% and Yolo sick bee detection scored 87%. The Deep Support Vector Data Description (SVDD) anomaly detector was tried out by the authors. The SVDD anomaly detector, yet, was unable to simulate the issue. The Jetson Nano can be an element of a detecting end-node device, according to the researchers. The authors' suggestion to use YOLOv5 yields noteworthy outcomes. However, there is no disclosure of detection performance findings. Furthermore, the F1 score metric, that evaluates the model's sensitivity and precision, does not accurately reflect the model's accuracy. Although not a reliable accuracy statistic, the mAP score implies a good accuracy model.

3. CONCLUSION

In conclusion, the fight against Varroa mite infestations in honey bee colonies is experiencing a transformative phase marked by the integration of innovative technologies. Traditional methods like bottom board counts and daily mite deaths remain valuable, but the multifaceted nature of Varroa mite dynamics demands a more diverse set of diagnostic tools.

E-nose technology, offers a breakthrough by analyzing hive air composition for early Varroa mite detection. The precision of the detection moment is crucial, emphasizing the significance of timely intervention in controlling infestations.

Sound monitoring systems, provide sophistication in Varroa mite identification by distinguishing various stressors and correlating colony collapse events with mite presence. The "sugar shake" method emerges as a simple yet effective technique for quick and accurate Varroa mite assessments on adult bees, drones, and entire colonies.

Washing kits with water or alcohol, offer an alternative for obtaining accurate mite counts on adult bees. Cloud computing and Wireless Sensor Network (WSN) technology present opportunities for real-time monitoring, but challenges like false positives need addressing.

Technological innovations like the Var-Gor device and experimental systems by showcase automation and early detection potential. Vision-based approaches, show promise in efficient Varroa mite identification. Collaboration between beekeepers, researchers, and technologists is essential for refining these methods and ensuring their practicality in real-world beekeeping scenarios. The continuous pursuit of accurate and scalable Varroa mite detection remains crucial for honey bee colony health worldwide.

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