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Detection of Varroa mites from honey bee hives by smart technology Var-Gor: a hive monitoring and image processing device

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Abstract: The major honey bee parasite *Varroa destructor* reduces hive vitality and honey yields by preventing growth of heathy bees and causes drastic loss in apiculture. Therefore, mite infestation in honey bee needs to be constantly controlled by beekeepers. To minimize this loss, a system called Var-Gor has been developed with the aim of controlling Varroa mite infestation before/just after entering the hive instead of the late period. Var-Gor is a hive entrance attachable device box consist of bee passage tunnels (width: 25 mm, height: 15 mm, and depth: 50 mm), autofocus detection camera combined with interface (process sensor: IV-HG10) and supportive image capturing equipment. Energy requirement of the device was provided by sustainable and eco-friendly solar panels and power batteries placed close to hives. Additionally, a Wi-Fi-like network connection and easy to use mobile application software was designed for the early warning of the beekeepers in case of *Varroa destructor* infestation. All the systems were designed compatible with cloud storage and 5G smart technology developments. Var-Gor was trained with 60% Varroa mite containing honey bees (*Apis mellifera* L.) and 40% not containing ones. The matching range of shapes to regular honey bee and Varroa mite was 70%. Following the training system, it was able to detect existing Varroa mites with the highest accuracy within the trained samples. Even though the system requires further training based on the location and color of the mite on bee, it is a promising smart technology device for early detection of the Varroa mites.

Key words: Apiculture, early detection, smart technology, *Varroa destructor*

1. Introduction

The crucial role of Honey bees (*Apis mellifera* L.) in life has been studied for a long time and is of great importance. Honey bees are key contributors to natural ecosystem functions as being principal pollinators allowing plants to reproduce and further increase the availability of crops [1]. Thus, they play the integral part supplying human diets with ensured essential micronutrients and farm families with regular incomes [2–4]. Unfortunately, over the last decades, dramatic honey bee losses have been reported throughout the world, putting first the bee colonies and than the food security at risk. Major reasons of the decline in vitality of bees include pollution, climate change, pesticides, and diseases. Even though bees can be affected by far too numerous pest, parasites, and diseases, Varroosis is one of the leading causes mortality among honey bee worldwide [5,6].

Varroa destructor and *V. jacobsoni* are honey bee parasite mites and causes Varroosis in honey bee colonies. Varroa mites damage brood (larvae & pupae) and adult bees by feeding on their hemolymph and leading to decreased body weight or shortened life span in honey bees [7–9]. Furthermore, Varroa either transfers harmful organisms like viruses to the bees or reduces their resistance to all kind of external diseases. Varroa mites can damage vitality of the contaminated hive from 30% up to 80% [10–12]. Hafi et al. [13] predicted an approximate cost that might be caused by Varroa in case of contamination for upcoming 30 years period in Australia. The overall expanses warried between 0.17 and 83 billion $ depending on the taken action plans. Another estimation done in Papua New Guinee related on economic loss caused by improper pollination of coffee beans because of bee mortality suggested that mean annual losses over 24 years period might be 4.1 million $ [14]. Chaudhary [15] also demonstrated in 34th International Beekeeping Congress APIMONDIA 2009, the economic burden caused by Varroa based bee mortality might be as drastic for India as like other countries with amounts from 0.30 to 4.4 million $.

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Due to its devastating effects, the control of Varroa mites has been an important part of maintaining the colony health. Up to the present, chemical control method is of great importance to reduce parasite intensity. Although there are various synthetic drugs used in chemical struggle of Varroa mites including formic or oxalic acid, amitraz, coumafos and derivatives, complete control of the parasites is still impossible. On top of it, constant application, misuse, and overuse of these drugs has created drug resistance in mite populations, stress development and loss in bee colonies and yield drop and chemical residue in honey bee products [16-19]. Reduction of unrequired consequences caused by chemical struggle is possible only by implementation of the proper method as early as possible. Only then an accurate diagnosis of Varroa mite's infestation for efficient mite control could be obtained. Detection and quantifying of Varroa mites in honey bee colonies can be achieved by various methods (Table). Generally, two mite detection methods, sugar shake, or chemical wash have been preferred by beekeepers due to their easy applicability [20]. However, as shown in Table, because of the number of negative points in usage of the common methods, search for more efficient alternative methods kept going with inclusion of the developing technology.

For advanced hive observation and control in recent years, alternative monitoring technologies and methods that continuously monitor the honey bee colonies have been developed. In this way, early detection of various colony anomalies as well as mite infestation might be cognizant of which can ensure greater success in mite control and prevention of parasite spread to other colonies. Moreover, by early detection of Varroa mite contamination ratios, chemical struggle will be limited with the lowest numbers of mite. Thus, by reduced usage of chemicals that are toxic to both the bees and humans, reduction in drug residues in bee products and occurrence of drug-resistance in Varroa populations can be achieved [20,21]. So far, to evaluate the condition of hives, assess colony parasite infestation and help to remove mites physically from honey bees, monitoring tools such as Hivetool[1], Arnia[2], and Hivemind[3] have been designed [21,22]. Additionally, several methods to detect the mites in honey bees' cells by video sequence processing [23], image processing techniques [24] and laser beam annihilation [21,25] have been devised to control honey bee mites. Despite the broad variety of systems for detecting Varroa on honey bees, none of them managed to provide high accuracy diagnostics. Therefore, the aim of this study was to develop an eco-friendly, sustainable, and smart imaging and prewarning system for early detection of *Varroa destructor* contamination in honey bee (*Apis mellifera* L.) colonies supported by an easy to use mobile application enabling the beekeeper to take the quickest battle action.

2. System design and application

2.1. System design

The main idea before designing the device was to develop something that will not only provide an easy solution for Varroa mite struggle but also compete with current technologic improvements and ecology requirements. On top of that, keeping bees out of stress during all the detection process has been kept on mind throughout the entire designing process. Result of all the stated priority combinations was gathered in the Var-Gor device box (Figure 1). For effective early detection of Varroa mites, Var-Gor was designed to monitor the hive entrance. Both device (IP67) and the device box are prepared durable and weather resistant for operating in outdoor. The device is composed of interface integrated autofocus camera (KEYENCE Corp., Mechelen, Belgium), software and power supply. Autofocus camera was chosen in miniature sizes for its ease in adjustability to all kinds of hives. It is placed within the device after calculation of the area viewing parameters for the best clarity image capturing. Based on the calculations, the ideal position for proper observation of honey bees throughout the passage by the camera was 50 mm above from the bee gateway passage (25 mm in width, 15 mm in height and 50 mm in depth). Autofocus camera (Sensor Head, IV-HG300CA) is equipped with 1/3 inch color CMOS sensor. Obtained images by autofocus camera are being processed at the integrated interface (Sensor amplifier, IV-HG10), which is capable of conducting one overall process cycle in only 150 ms. Thus, due to advanced capabilities of the device, within one second seven images of the same bee are getting processed and compared with each other for the one and only final decision. During each processing cycle, every image is getting matched to the developed template filter, then classified according to color and got segmented. For the matching template algorithm, because of the high likelihood of elliptical and brown misleading shape of the Varroa mite, matching template filter was developed primarily based on the relatively unique shape of the bee. Therefore, as the first step, a standard bee shape was defined to the interface by creating a filter algorithm. Threshold of at least 75% similarity to the created bee shape algorithm was required for each captured image for successful template matching step. By this, the possibility of obtaining incorrect results was reduced to the lowest rates. In the case of Varroa mite

[1] HiveTool (2019). Hive Monitor Kit [online]. Website http://www.hivetool.net [accessed on 28.12.2019].

[2] Arnia (2019). Arnia remote hive monitoring [online]. Website https://www.arnia.co.uk [accessed on 28.12.2019].

[3] Hivemind (2019). Hivemind precision apiculture [online]. Website https://hivemind.nz [accessed on 28.12.2019].

Table. Comparison of Varroa mite detection methods based on their properties.

Varroa detection methods	Easy in application	Time efficiency	High labor demand	Electrical device requirement	Quick Action time	Excessive bee requirement	Hive and bee damage risk	Bee Mortality	Chemical residue	**Eco-friendliness**	**Sustain-ability**	**Innova-tiveness**	**High Cost**
Sugar Shake [26,27]	√		√			√		√		√			
Chemical Wash [28,29]	√		√				√	√	√				
Physical Observation [29-31]			√	√		√	√	√					√
Var-Gor	√	√		√	√					√	√	√	√

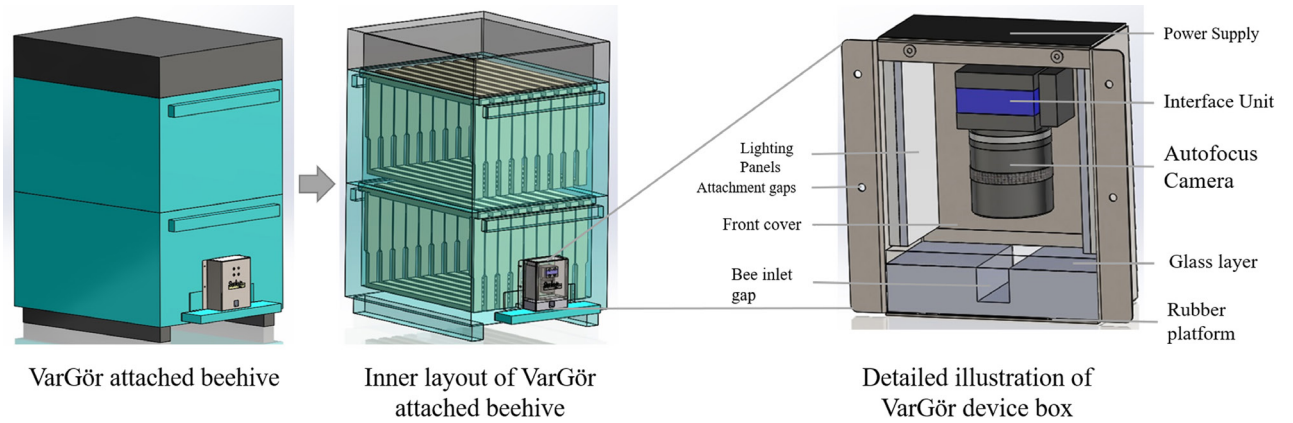

Figure 1. Interior design illustration of the Var-Gor device box.

matching template algorithm creation, additional to the Varroa mite specific elliptical shape filter, also filters of color classification and segmentation was included. Thus, the Varroa mites on bees were distinguished from Varroa free bees by double filter examination of both mite shape and color. By this, the threshold for similarity to Varroa mite on the bee increased to 80%, which is 5% higher compared to bee shape matching template with 75%. At the end of the process, identification accuracy in infected or healthy bee detection improved.

Following the device, a software compatible with Android tablets and smart phones was designed for the notification of the beekeepers (Figure 2). The interface of the software was kept as simple as possible for easy usage including not only verbal statements but also image displays. Basically, the screen of a hive without any Varroa contamination will display a bee image with green wing and state 'Clean' statement (Figure 2). However, at the moment, there is a Varroa mite detection, the screen will change to a bug image and state 'Varroa detected!' in a red colored statement (Figure 2). The notifications will be transmitted and updated constantly via Wi-Fi like a network connection. Given the fast developments in technology, the software was prepared adjustable for cloud storage processing and 5G smart applications.

The power supply of Var-Gor was designed to be obtained by solar panel generated energy. Sustainability and eco-friendliness of the energy source was primary concerns while designing. Given the activity periods of bees, solar panels were selected as the main energy-generating sources. Since the generation yield of the energy will be based on the numbers of sunny days, the choice of the battery capacity and its power storability will be adjustable. According to the rate of sunny to unsunny days of the used region, needed back-up energy will be calculated and the solar panel with 75% higher energy storage capacity will be integrated to the device. Thus, the energy feed will be guaranteed all of the bee activity period around.

2.2. System application

The initial trials of Var-Gor device were conducted in the same laboratory environment as it has been designed. Thus, as the main energy source, instead of solar energy panels, regular electricity was used. During the primary

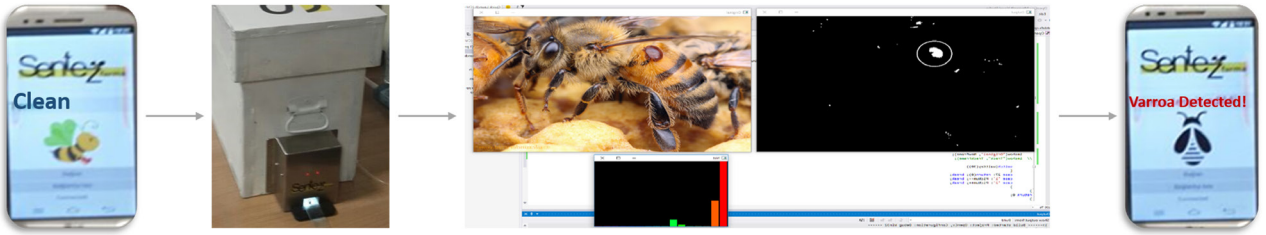

Figure 2. Overall process of Var-Gor early warming system.

trials of the device, it was trained with a number of bees. Among the trained bees, 60% of the bees were carrying Varroa mite while the rest were not.

As overall detection and warning cycle shown in Figure 2, those honey bees attempting to enter the hive passed in front of the camera ideally placed in the hive entrance and got monitored by continues capturing of their RGB images. Obtained images of the bees were transferred to the interface where it was processed with an average speed of 10 Hz. During this process, images were initially being matched to trained bee shape template filter, then matched to trained mite shape template, classified by mite color and got segmented based on defined three different filters. All of the cycles were repeated for seven times and finally one result was maintained. If the bee was from ones that contained Varroa mite, the mite got detected, as a result, an alert was sent to the smart phones with the help of wireless communication system (Figure 2). Thereby, a bug contamination notification and the fast warning was obtained successfully. Although, we still need to keep under consideration that these results were obtained only within the trained samples and in laboratory conditions, still, according to the results, the success rate of the device in Varroa mite detection was 100%.

3. Conclusion

Energized by sustainable solar energy panels, to the best of our knowledge, the first in the implementations of image-processing for monitoring Varroa mites on honey bees in Turkey, the Var-Gor device was designed. During the design and trials, absolute success in Varroa mite detection and warning has been obtained. Additionally, new challenges such as place of the Varroa mite on the bee and the color based on its maturity were faced and consideration for upcoming updates were taken. Laboratory trials of the device, in general, were encouraging to keep working on the device for better improvements. Overall, based on its eco-friendly and sustainable nature, accurate results and futuristic design, Var-Gor is a promising device for the early detection of Varroa mite as well as its early struggle.

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Conflict of interest

The authors declare that there is no conflict of interest.

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