

Sharing is caring: Validation of the Varroa alert system, a freely accessible, web-based data sharing platform for beekeepers

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Abstract

Coordinated and timely actions based on real time information and preventive risk management are important prerequisites for efficient control of *Varroa destructor*. After a successful pilot project, the Austrian Chamber of Agriculture (LKO) together with other stakeholders (BÖ, AGES) has launched a freely accessible, web-based data sharing platform (www.bienengesundheit.at), which collects and analyses mite load data assessed by beekeepers enrolled in a sentinel apiary program. A predictive algorithm extrapolates mite loads in individual colonies assessed with a standardised method (natural mite fall) at different times of the year. Based on these predictions the system performs risk assessments at a regional level. If mite loads are expected to exceed a predefined threshold, the system triggers an alert, which is subsequently published on different communications channels (social media, e-mail, website). Predictions can be customized by the user to test the effect of treatments and brood rearing activity on mite populations. Based on weather forecast data, the system issues region specific recommendations for an efficient application of veterinary drugs whose efficacy is temperature dependent. The database currently includes 7545 samples from 86 beekeepers and 1288 colonies tagged with their geographic position from 8 years. Currently, an API is being developed that will allow beekeepers using hive management software to transmit mite counts to the database. This function is expected to further increase data flow to the platform. In 2018, a newly developed diagnostic system (BeeVS®) using high resolution cameras for data acquisition and a cloud-based artificial intelligence for data analysis has been integrated in the sentinel apiary program. BeeVS® is able to detect and count Varroa mites on sticky boards in the field with high precision and sensitivity, thereby assuring data traceability and data quality. The BeeVS® database includes >425.000 high resolution Varroa images.

Material and Methods

The VarroaAlert database contains samples of infestation rates of Varroa mites (*Varroa destructor*) in managed honey bee colonies from 2012 to 2019, assessed with a standard method (natural mite fall measured with sticky boards) described by Dietermann *et al.* (2013). Varroa samples come from three sources differing in data quality: High quality samples are analysed by trained and supervised individuals with the BeeVS® diagnostic system, consisting of high-resolution cameras for data acquisition and a cloud-based artificial intelligence for data analysis. Medium quality samples are analysed manually by trained and supervised individuals. Samples of unknown quality are analysed by individuals enrolled in a sentinel apiary program following a recommended sampling scheme. Samples are predominantly taken in early spring and in early and late summer, but sampling is possible at any time of the year. Data is generally entered via a web terminal (www.bienengesundheit.at) by the individual who analyses the samples. Data entered into the database is checked automatically by the software for plausibility and completeness and manually by the supervisor of the crowd-sourcing project. For each sample, additional information such as the ID-number of the hive as well as ZIP code, coordinates and elevation above sea level of the apiary (provided by the user) are recorded. Mite loads are expressed as mites day⁻¹. The BeeVS® diagnostic system (version 41) has been validated in 2018 according to the Guideline on Bioanalytical Method Validation issued by EMEA (2011) in Good Field Practice (OECD 1999). The parameters assessed were precision (repeatability), accuracy, lower level of quantification (LLOQ), selectivity and stability. A comparison was made between the performance of the BeeVS® diagnostic system and manual counts by trained human operators.

Results and Discussion

The VarroaAlert web platform www.bienengesundheit.at was launched in August 2017 after a 5-years test run at regional level. It consists of a publicly available front end offering a complete set of information on Varroa control (general risk analysis, user defined predictions, weather based recommendations for Varroa treatments, guidelines for diagnosis and information on veterinary drugs) and a private back end for data management and a risk analysis for individual colonies and apiaries. Based on the results of the risk analysis, alerts are triggered and disseminated via various channels (websites, e-mail and social media).

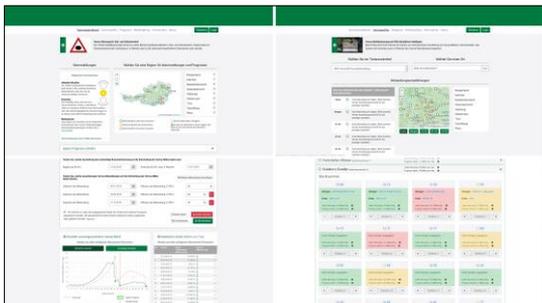


Figure 1. Screenshots of the VarroaAlert website (www.bienengesundheit.at). General risk assessment based on results from sentinel apiaries (upper left), weather-based recommendations for Varroa treatments (upper right), user defined simulation of Varroa control measures (lower left) and, risk assessments for individual hives (lower right).

Currently there are 73 active sentinel apiaries with 664 active sentinel hives, representing 0.2% of the total number of managed hives estimated to be kept in Austria. In total the database contains 7545 samples of Varroa infestation rates, of which 19% are considered high quality and 21% medium quality samples. There is a bias in the origin of the samples. One user provided 29% of the samples, 47% of the samples come from 15 users who provided a total of 100-999 samples, 23% of the samples come from 50 users who provided a total of 10-99 samples and 1% of the samples were provided by 20 users who have entered less than 10 samples. The number of samples per week of the year ranges from 10 to 478 (Figure 2). In 2018 the website counted 93,340 visits. Considering that there were 29,745 officially registered beekeepers and that 74% of the accesses were made by domains located in Austria, on the average each Austrian beekeeper made use of this freely accessible consultancy service 2.3 times per year.

year	active users	active apiaries	active hives	samples	total hives	website visits
2012	2	6	60	120	54.933 ¹	-
2013	2	6	51	51	55.702 ¹	7.032
2014	2	6	81	211	54.453 ¹	23.078
2015	5	9	148	600	52.721 ¹	35.527
2016	7	11	143	670	52.489 ¹	38.044
2017	62	117	624	2.305	353.267 ²	95.636
2018	35	61	380	1.761	372.889 ²	93.340
2019	39	73	664	1.827	n.A. ²	42.013

Table 1. Number of users, apiaries, hives and samples in the VarroaAlert database and the total amount of hives kept in the area covered by the sentinel apiary program (Region of Styria, Austria including Styria). Data for 2019 comprises all samples entered until 19.08.19. n.A., data not available. Source: Austrian Beekeeping Federation (BÖ).

In order to provide a continuously updated risk assessment, mite loads in colonies assessed before the current week have to be interpolated with a

predictive algorithm, which processes parameters such as the samples of the current year, the relative growth rate of the mite population in a colony (if more than one sample is available in a given year), the rate of oviposition by the queen and the management practice of beekeepers (Figure 2). Based on measured and predicted values of all hives located in the same geographic region, a risk assessment is periodically generated. If predicted mite loads exceed a predefined threshold in a region, an alert is triggered by the system, requesting confirmation by a human administrator.

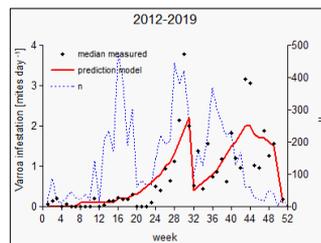


Figure 2. Summary of the samples contained in the VarroaAlert database. Left y-axis: Average (median) natural mite fall [mites sites⁻¹] in 1288 colonies at 210 different sites (n=10-479) measured from 2012 to 2019 (black dots) and best fitting prediction of natural mite fall [mites day⁻¹] using the VarroaAlert prediction model with a growth rate (R_0) of 0.03391 mites mite⁻¹ day⁻¹ and an initial mite load (R_0) of 9 mites colony⁻¹ (red line). Right y-axis: Number of samples (blue dotted line). X-axis: Week of the year.

In 2019, 56% of the samples entered in the database were measured with the BeeVS® diagnostic system. As compared to manual counting by human operators, BeeVS® had a clearly (up to 3.7 fold) higher intra-run precision, while intra-run accuracy was only slightly better (Figure 3). LLOQ ranged between 1,9 and 4,5 mites day⁻¹, depending on the validation run. Samples collected with sticky papers were stable for up to 4 weeks at 12°C and could be transported without losing accuracy. The time required to manually count a sample was on the average 3 times higher (2.7 minutes longer) than the time required to analyse a sample with the BeeVS® diagnostic system.

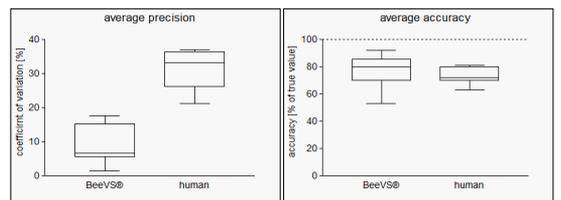


Figure 3. Performance of the BeeVS® diagnostic system (algorithm version 41) as compared to the results obtained by 5 human operators for samples \geq Lower level of quantification ($n=11$). Average precision (left), expressed as coefficient of variation of 5 measurements of the same sticky board. Average accuracy (right), expressed as the percentage of the true value. Boxes: Q₁, median, Q₃; whiskers: maximum, minimum.

Since the validation in 2018, the performance of the BeeVS® analytical algorithm has been further improved by means on an evaluation of approximately 150.000 test images (currently version 44).



Conclusions

- The Varroa alert system, which allows beekeepers enrolled in a sentinel apiary program to share results of Varroa diagnosis in real time using a simple and automated method for sampling, data processing and risk assessment, may be an efficient tool to reduce the impact of Varroosis on the beekeeping industry.
- Samples measured in the context of this program may be used to develop and improve strategies to control the Varroa mite.
- The BeeVS® diagnostic system has proven to greatly help monitoring Varroa infestations, eliminating the onerous task of counting the mites manually, ensuring a good accuracy and a better homogeneity and reproducibility of results compared to human operators.

References

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