Winter honey bee colony losses, *Varroa destructor* control strategies, and the role of weather conditions: Results from a survey among beekeepers

Marco Beyer⁎, Jürgen Junk⁎, Michael Eickermann⁎, Antoine Clermont⁎, François Kraus⁎, Carlo Georges⁎, Andreas Reichart⁎, Lucien Hoffmann⁎

⁎ Luxembourg Institute of Science and Technology (LIST), Department Environmental Research and Innovation, 41, rue du Brill, Belvaux L-4422, Luxembourg
⁎⁎ Administration des Services Techniques de l’Agriculture (ASTA), B.P.1904, Luxembourg L-1019, Luxembourg
⁎⁎⁎ Fédération des Unions d’Apiculteurs (FUAL) du Grand-Duché de, Luxembourg

**A R T I C L E   I N F O**

Keywords:
Apis mellifera
Varroa destructor
Parasite control
Pollinator decline

**A B S T R A C T**

Sets of treatments that were applied against varroa mites in the Luxembourgish beekeeper community were surveyed annually with a questionnaire between the winters 2010/11 and 2014/15. The average temperature and the precipitation sum of the month, when the respective varroa control method was applied were considered as co-variables when evaluating the efficacy of varroa control regimes. Success or failure of control regimes was evaluated based on the percentage of colonies lost per apiary in the winter following the treatment(s). Neither a positive nor a negative effect of formic acid (concentration 60%, w/v) on the colony losses could be found, irrespective of the weather conditions around the time of application. The higher concentration of 85% formic acid was linked with reduced colony losses when applications were done in August. Colony losses were reduced when Thymovar was applied in July or August, but applications in September were associated with increased losses compared with apiaries not treated with Thymovar during the same period. Apilife application in July as well as Apivar applications between July and September were associated with reduced colony losses. The removal of the drone brood and trickled oxalic acid application had beneficial effects when being done in April and December, respectively. Relatively warm (3.0 ± 1.3 °C) and wet (507.0 ± 38.6 mm/2 months) conditions during the winter months December and January and relatively cool (17.2 ± 1.4 °C average monthly temperature) and wet (110.8 ± 55.5 mm/month) conditions in July were associated with elevated honey bee colony losses.

1. Introduction

High losses of managed honey bee colonies have recently been reported from many regions of the world (van der Zee et al., 2012; vanEngelsdorp et al., 2012; Clermont et al., 2015a), raising concerns that a global pollinator decline could be going on. Among other factors, the survival of honey bee colonies in winter strongly depends on the infestation levels with *Varroa destructor*. *Varroa destructor* (Anderson and Trueman, 2000) is a parasitic mite and a major pest of Western honey bees (*Apis mellifera*). The mites feed on the hemolymph of the larvae and the adult honey bees. They reproduce in the brood cells of developing bees. The mite is a vector of several honey bee viruses (Rosenkranz et al., 2010; Genersch, 2010). Numerous studies demonstrated that varroa mites and associated viruses contributed significantly to honey bee colony losses worldwide (Guzmán-Novoa et al., 2005; Francis et al., 2013; Clermont et al., 2015b; Möntus et al., 2016). The control of the mites is therefore crucial for successful beekeeping.

Since the first reports of the spread of *V. destructor* to Europe in the late 1980s were published, several control techniques were suggested such as the application of organic acids (formic acid (Giusti et al., 2017), oxalic acid (Al Toufailia et al., 2015)), application of essential oils such as thymol (Gregorc et al., 2017), the use of synthetic acaricides (amitraz, flumethrin), and, several biotechnical methods (removal of drone brood, occasionally brood interruption). Other strategies such as heat treatment and chemo-ecological approaches like mating disruption by pheromone exposure were occasionally used in experimental apiaries (Ziegelmann and Rosenkranz, 2014).

The use of synthetic acaricides is associated with the risk of residue accumulation of the acaricides and their degradation products in the wax (Korta et al., 2003). Mite populations from several countries were found to be (cross-) resistant to acaricides such as amitraz and fluvinate (Elzen et al., 2000; Sammataro et al., 2005). Formic acid was...
shown to be efficient against phoretic and reproductive mites (vanEngelsdorp et al., 2008). Oxalic acid is usually applied in broodless colonies during winter (Emsen and Dodologlu, 2009; Rosenkranz et al., 2010).

The climate in the area surveyed is temperate without extreme fluctuations with a tendency towards cold and damp. Average temperatures range from 0 °C in January to 18 °C in July with an annual average of 9 °C. The total average annual rainfall is around 830 mm with a rather homogenous temporal distribution over the year (https://en.climate-data.org/location/984/). Giacobino et al. (2017) recently provided evidence that environmental factors are a predominant driver of V. destructor infestation levels. Furthermore, beekeepers and producers of organic varroa control products claim that the efficacy of the products depends on weather conditions around the time of their application. We therefore hypothesize that the consideration of weather conditions will enhance our knowledge on the time frames when varroa applications are successful with regard to winter colony losses.

The objectives of the present study were (1) to establish associations between commonly used varroa control strategies and honey bee colony losses and (2) the identification of application time frames that were linked with low colony losses when weather conditions around the time of application were considered.

2. Materials and methods

2.1. Data acquisition

All managed bee colonies in Luxembourg must be registered at the national veterinary administration to allow for the coordinated control of honey bee pests and diseases. A registration form is sent to each beekeeper every year. Since the winter of 2010/11, the Luxembourg Institute of Science and Technology (LIST, formerly Centre de Recherche Public - Gabriel Lippmann) attached a questionnaire to the registration form. In 2015, 6360 colonies subdivided into 912 apiaries and managed by 366 beekeepers were registered at the local veterinary administration. The participation to the survey was voluntary. Researchers and the staff of the local veterinary administration advertised the questionnaire in beekeeper meetings for participation. The questions raised in the survey were listed in Clermont et al. (2014). Among other questions, the kind (product) and timing (months of treatment) of varroa control methods as well as the level of winter colony losses was asked. The responses received were checked for consistency and freedom of contradictions. Contradictory data sets were excluded from data analysis. Furthermore, data sets where the beekeeper was not willing to share the geographic coordinates of the apiary could not be used, because the closest weather station could not be determined reliably in those cases. After excluding incomplete and contradictory data sets, data from a total of 705 apiaries managed by 323 beekeepers were available for the present study. The total number of ‘apiary × year’ combinations was 1364. If, for instance, the same three apiaries were treated in the same manner over 4 years, 12 ‘apiary × year’ combinations would be obtained for the treatment under investigation.

The average experience in beekeeping of the participating beekeepers was 15 years. The data of the survey were anonymized by the national veterinary administration and statistically analyzed at the Luxembourg Institute of Science and Technology. Here, we present results from five survey years (period 2010/11–2014/15). Honey bees are largely kept in stationary apiaries for honey production in relatively small operations with a medium number of 8 colonies per apiary in the area studied. In a previous study carried out in the same region surveyed here, the first colonies that did not survive the winter died in October and the last ones in March (Clermont et al., 2015b). The major honeybee genotypes that are covered by the present survey were Buckfast and Carnica with Buckfast being by far more popular in the region surveyed (Clermont et al., 2015a).

Meteorological data were retrieved from three different data sources. We used data from the SYNOP (surface synoptic observations) station at Luxembourg-Findel Airport (WMO station ID = 065900) located in the south-east of the City of Luxembourg. Furthermore, we used data from the meteorological network of the Luxembourg Institute of Science and Technology. These sites were equipped with standard automatic weather stations (AWS). Last, data were taken from the meteorological monitoring network of the “Administration des Services Techniques de l’ Agriculture”. At all stations, air meteorological variables were measured at the standard heights; air temperature and relative humidity at 2 m and total precipitation at 1 m above ground. The uncorrected data from the different data sources were subsequently pre-processed using an automatic data processing chain including error detection and correction as well as linear gap interpolation procedures according to the method described in WMO (1995). Stations where > 5% of the data in an individual time series were missing were excluded from the further processing. Based on 10-minute-values, monthly averages for air temperature and totals for precipitation were calculated. A total of 26 weather stations delivered data that passed the quality tests described above throughout the period of observation. The closest weather station was identified for each apiary using the near tool of the software package ArcGIS (ArcGIS software 10.0, ESRI, 2003) and the weather conditions measured by the closest weather station were assumed to be the same at the position of the apiaries surrounding it. The distance between apiary and weather station ranged from 0.32 km to 12.47 km. The median distance was 5.48 km. The position of the weather stations and the apiaries is shown in Fig. 1.

2.2. Data analyses

Apiaries were grouped according to the similarity of the varroa control regimes concerning the kind of chemical(s) and biotechnological methods used as well as by the timing of the treatment using a

![Fig. 1. Position of apiaries (colored points) and weather stations (⊙) that were used in the present study. The closest weather station was determined for each apiary using the near tool of the software package ArcGIS. Apiaries with the same color were assigned to the same weather station in the center of the group of points based on proximity.](image-url)
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات