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AN OVERVIEW ON BEEKEEPING AND HONEYBEE COLONY LOSSES IN ROMANIA, RESULTING FROM NATIONAL SURVEYS

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Abstract

The use of questionnaire in beekeeping has been proved as an important tool of collecting valuable statistic data and answer particular questions. In the period 2014-2023 we launched different questionnaires at national level with the main purpose to evaluate the situation of honeybee colony losses (Apis mellifera) and possible causes. The main results on different questions are illustrated and analysed in the present paper, offering a general view on Romanian beekeeping, honeybee colony losses and associated causes. The preliminary data on validated questionnaires show that, the rate of honeybee colony loss registered values between 5.0% in 2015 and 17.0% in 2022/2023 winter season. Out of the total number of respondents and on the whole surveyed period, an average of 32.7% respondents registered mortalities over 10% at the apiary level, and 56.5% registered depopulations over 10%, with variations between different periods (years, months). Having an overview on the rate and incidence of colony losses in the last years and possible factors affecting honeybees can help the involved stakeholders to support the beekeeping field and adapt it to future challenges.

Key words*: beekeeping, honeybee colony losses, questionnaire, survey, Romania.*

INTRODUCTION

The honey bees (*Apis mellifera* L.) have an important contribution to the welfare and balance of natural ecosystems as well as in the human nutrition and health (Goulson et al., 2015; Cherbuliez, 2013; Gallai et al., 2009). Both, for production and pollination, the honeybee colonies have to be well developed. To capitalize the main nectar flows, the beekeepers have to implement an optimal management of honeybee population in different periods of the year, taking into account the biologic cycle and natural local conditions (Graham, 1999). To overpass the critical periods (drought, winter), the colony strength and physiologic parameters are very important, too (Somerville, 2005).

Romania's climate is a transitional temperate-continental, marked by some oceanic, continental, Scandinavian-Baltic, Mediterranean and Pontic climatic influences (https://www.meteoromania.ro).

The local honey bee (*A. m. carpatica)* (Foti et al., 1965), reconfirmed by recent studies (Oleksa et al., 2023; Chen et al., 2022; Tofilski et al., 2021; Momeni et al., 2021) is very important to be preserved for sustainable breeding and beekeeping as natural patrimony. The selection pressure, by natural (e.g. flora, temperature, diseases) and artificial conditions (e.g. beekeepers' management, flora and land use) could have a negative impact on honey bee diversity and resilience (Meixner et al., 2010; de la Rua et al., 2009).

In Romania, the beekeeping management follows specific stages correlated with the seasons, beginning with winter honeybee rearing period (August-October), continuing with the wintering period (November-February), partially overlapped by the period of replacing the wintering bee (January-April), followed by the swarming period (end April-June) which covers also the largest period of honey production (Mateescu et al., 2012). The differences in the length of active and inactive seasons depend on climatic yearly variations, altitude or latitude. Thus, the beekeeper's management should aim the maximization of biologic potential to develop or maintain the population by controlling the reproduction, space, nutrition, storages, swarming, diseases and pests, etc.

Independent or dependent of beekeeper's management, a series of population losses occur each year as seasonal losses, connected with

many causing factors. In wintering season, in Romania, the colony losses at the level of an apiary are considered acceptable under 10% (Mateescu et al., 2012), similarly with other European countries (Gray et al., 2019). In USA a threshold of up to 19.8% was recently calculated to be acceptable for different categories of apiaries (Bruckner et al., 2023; Kulhanek et al., 2017). This difference is expected because the beekeepers' structure regarding the operation size is very different in the two regions, with larger, commercial apiaries in USA, than in EU, comprising the most part of country stock. Generally, the losses could take the form of mortalities (totally lost colonies) and/or depopulations (weak colonies) with different levels of population loss (van der Zee et al., 2013). As a consequence, the population and apiary's profitability are affected proportionally with the level of population loss. The loss rates in autumn, winter, early spring or summer are very important as they influence the number of production colonies in the next active season. To make data comparable and to guideline different stakeholders for conducting effective surveys to identify the winter colony loss rates and risk factors, a series of standardized questionnaires as well as recommendations were developed and published within COLOSS - Honey Bee Research Association - Citizen Science "Colony Losses Monitoring" Group (van der Zee et al., 2013; https://coloss.org). The standardized survey for winter colony loss monitoring was developed to measure the colony loss rates in spring based on the quantification of colonies' number at the beginning of winter and how many of these colonies were dead or reduced to a few hundreds of bees in spring, or had unsolvable problems (drone-laying, lack of queens).

At international level, honeybee colony losses are frequently reported and in the last years (2012-2020), the level of winter colony loss was reported almost annually (Bruckner et al., 2023; Gray et al., 2023; Steinhauer et al., 2023; Gray et al., 2020; Gray et al., 2019; Brodschneider et al., 2018; Kulhanek et al., 2017; van der Zee et al., 2016; van der Zee et al., 2014).

The overall winter loss rate was established in 2015/2016 at 12% (29 countries), in 2016/2017 at 20.9% (27 countries), in 2017/2018 at 16.4% (36 countries), in 2018/2019 at 16.7% (35 countries) and in 2019/2020 at 18.1% (36 countries), with significant differences between countries and years (from less than 5% to even more than 30%). At European Union level, the reported loss rates were as follow: 17.9% in 2017/2018, 14.5% in 2018/2019, and 17.7% in 2019/2020 (Gray et al., 2023; Gray et al., 2020; Gray et al., 2019; Brodschneider et al., 2018; van der Zee et al., 2016; van der Zee et al., 2014).

Romania was part of one of these studies (2019/2020), being reported an overall loss rate of 15% (CI 95%: 11.9-18.8%) ranked in the middle loss rate (Gray et al., 2023). The information was collected from 121 respondents (8298 colonies), representing less than 1% of total beekeepers in the country.

In a recent document published by the Ministry of Agriculture and Rural Development in Romania in the National Strategic Plan (2022, https://www.madr.ro) there are reported 32864 registered beekeepers who manage 2.352 mil. honey bee colonies. The larger apiaries with more than 150 colonies, who proved to register lower colony losses in Europe (Gray et al., 2020), are managed in Romania by 9.28% of total beekeepers (professional category), owning 26.9% out of the total number of colonies. This means that for almost ¾ of the colonies stock there are increasing risks to register colony losses, affecting the local honeybee diversity and beekeeping economy.

As multiyear data show, the questionnaire became an extremely important tool to collect useful information in a certain area or for a certain critical period. Its composition could change depending on the characteristics of studied population (country, practices, length of active season, etc.) or other interest variables (Bruckner et al., 2023; Gray et al., 2023). An increased rate of questionnaire completion and its regular application could help obtaining important information by analysis of data in time perspective (Brodschneider et al., 2022). To collect general information on beekeeping and honey bee colony losses (depopulation and mortality), together with assessing the possible causes of them, different questionnaires were launched in the 2014-2023 period in Romania. Therefore, the objective of this paper was to perform a preliminary analysis of the collected

data in order to assess the situation of colony losses in Romania and explain the possible causes. The obtained results offer a general view on Romanian beekeeping in the last years, data on the incidence of colony losses among the beekeepers, the mortality rate on subsets of validated questionnaires, as well as a synthetic evaluation of possible causes.

MATERIALS AND METHODS

Taking into account the multifactorial causes of colony losses from critical periods, generally incriminated worldwide, (e.g. varroa, phytosanitary treatments, nutrition) we chosen in our study a multi-questions survey (17-28 questions) in order to collect general information from beekeeping field combined with the estimation of colony losses and their possible causes in 2014-2023 period. The composition of questionnaire, the format (online/onsite) and evaluated periods were relatively variable, therefore, the data sets of respondents were selected and validated for certain questions of interest or period in order to be compared and statistically analysed. Following the validation process, the data on the number of questionnaires (respondents) for general questions about local beekeeping were recorded, from which respondents who provided data on registered number of colonies and associated loss were extracted for the calculation of the colony mortality rate (Table 1).

To evaluate the structure of respondents to a specific question and for a certain implementing period the response variable was represented by the total percentage of respondents.

To establish the overwinter mortality rate, the number of colonies registered and the associated colony loss were calculated for each validated questionnaire and set of questionnaires. In order to more accurately assess this indicator for the winter season 2022/2023, as the number of questionnaires validated for colony mortality rate calculation was low, we included a telephone interview conducted in 2023, on a subset of respondents from the online questionnaires. The loss rate of honeybee colonies expressed as mortality percentage during the winter period (November-April), was calculated by reporting the number of surviving honeybee colonies in the spring to the total number of colonies recorded at the beginning of winter (Bruckner et al., 2023; Gray et al., 2023, van der Zee et al., 2013). In the interview carried out in 2023 (71 questionnaires) we had the opportunity to re-evaluate and validate the loss rate for the winter 2022/2023 mortalities, as well as to evaluate the autumn mortality rate for August-October 2022 period, asking, case by case, information about possible causes.

The incidence of honeybee colony losses among beekeepers/apiaries was also reported as a percentage of respondents experiencing colonies' mortality or depopulation of more than 10%.

The results were analysed and presented tabularly or graphically for a better highlight of the multi-year situation. In this regard, the collected data were centralized through the Google survey platform and Excel Office files as well as analysed and synthetically presented by means of the NCSS 2021 Statistical Software, 2021.

RESULTS

1. Number of responding beekeepers

Table 1 presents the centralized data on the number of validated questionnaires for general information about beekeeping, as well as on the validated questionnaires for the calculation of the loss rate. For general questions the highest share of respondents (37.8%) was recorded in 2023 (278 questionnaires), followed by 30.9% in 2017, 12.9% in 2019, 11.6% in 2015 and 6.8% in 2016. Of these questionnaires, 58.3% were completed online, with the majority completed in 2023 (41.9%). The questionnaires were collected from all over the country (42 counties - Figure 1), but the validated ones for the loss rate were registered from 35 counties (including interview from 21 counties).

From the Table 1 and Figure 1 it can be seen that there is a relatively uneven distribution of respondents, both over the studied period and per country. It is important to mention here that in certain counties (Bacău, Dâmbovița, Gorj, Neamț, Sălaj, Sibiu, Timiș, Vaslui, Vrancea) a higher number of respondents was registered as a result of completing the questionnaires during the associative meetings, using the online or printed questionnaires (onsite).

In order to calculate the colony loss, only questionnaires that recorded accurate data on apiary size and winter mortality were used. For this purpose, 244 questionnaires (79.4%) of the total completed in printed format were validated. To check the obtained results in 2023, 71 beekeepers from the 2023 online data set of questionnaires, originating from 21 counties were interviewed. By reference to the published data on the total number of beekeepers, the percentage of participation in completing the questionnaire was generally below 1%. For example, compared to the most recent published data on the number of beekeepers in Romania (E.U. 2020-2022: n = 2316; https://agriculture.ec.europa.eu), the number of respondents who completed the questionnaire launched in 2023 was 1.2%, and in the case of validated questionnaires for loss rate the percentage was 0.57%.

Table 1. Number of validated questionnaires (respondents) by period, method of completion and number of participated counties

Survey	Validated questionnaires for general questions [Validated questionnaires for calculation the mortality rate of honeybee colonies]						
	2014/2015 (n)	2015/2016 (n)	2016/2017 (n)	2019 (n)	2022/2023 (n)	Total	
						(n)	%
Onsite	86 [67]	50 [49]	73 [66]	N/A	98 [62]	307 [244]	41.7 [77.5]
Online/*Interview	N/A	N/A	155	95	180 *[71]	430 *[71]	58.3 *[22.5]
Total	86 [67]	50 [49]	228 [66]	95	278 [133]	737 [315]	100
Number of participated counties	38 [19]	37 [8]	41 [9]	8	23 [21]	42 [35]	100 [83.3]

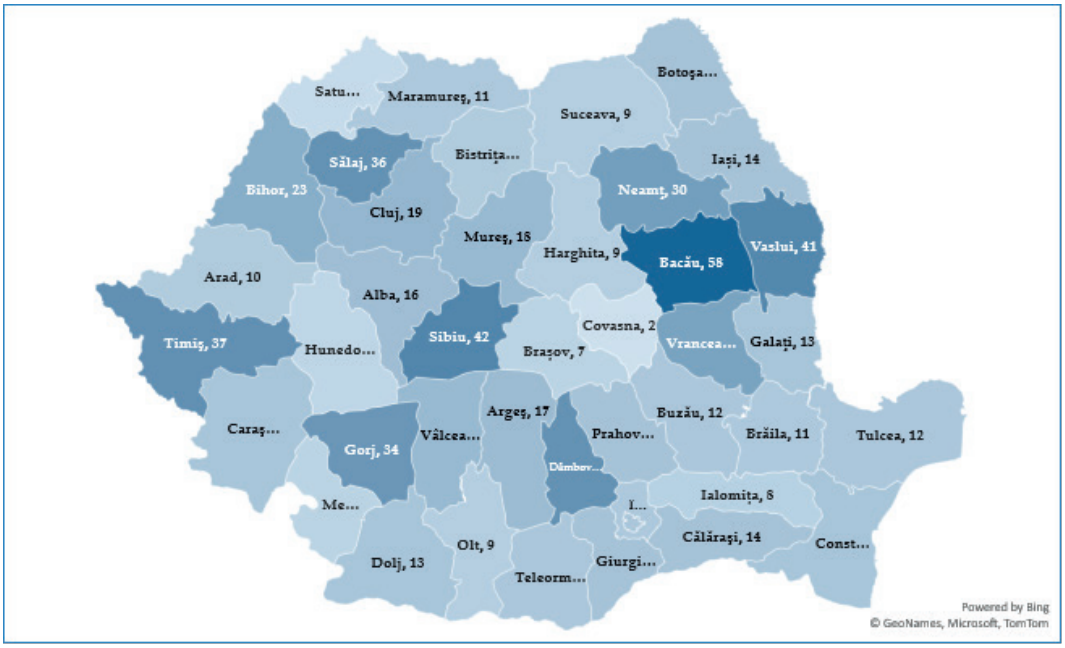


Figure 1. The map of the number of respondents' distribution (Romania, 2014-2023)

2. General data regarding beekeeping in Romania

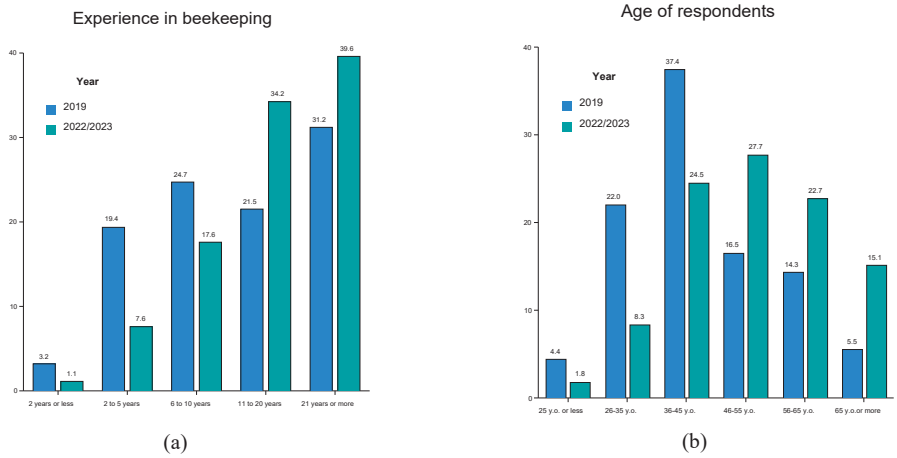
Comparisons were made between data sets collected in 2019 and 2022/2023 when the questions regarding general data on beekeeping in Romania were included in the surveys.

2.1. Experience in beekeeping and age of respondents

From Figures 2a and 2b, it can be seen that the majority of respondents are experienced beekeepers (52.7% - 2019; 73.8% - 2022/2023), with over eleven years of activity, but relatively young, between 26 and 55 years old (75.9% - 2019; 60.5% - 2022/2023). In the case of the 2019 survey completed entirely online, the share of beekeepers with less experience (< 11 years) of the total respondents is higher (47.3%) compared to the results obtained by the combined way of completing (onsite and online), in 2022/2023, where the share of beekeepers with less experience decreases (< 11 years; 26.3%).

This is expected because the percentage of younger respondents (under 45 years; 34.6%) is lower in the results obtained in 2023 (Figure 2b) compared to 2019 (less than 45 years; 63.8%), a fact that indicates the different structure of the participants in the two social environments (online and combined). The situation is probably influenced by the lower participation of younger beekeepers with less experience in the associative beekeeping meetings, which especially contributed to the increase in the number of questionnaires collected in 2023.

These recent data can provide a better picture of the situation that could be extrapolated to the whole country.

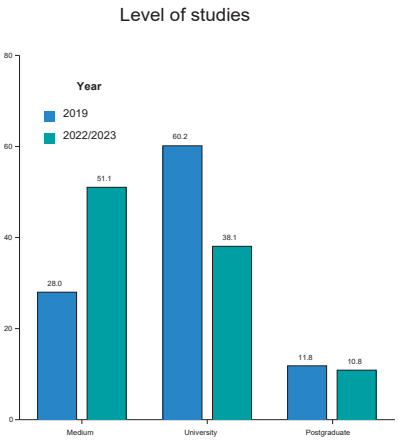


(a) (b)

Figure 2. The structure of respondents (%) regarding the experience in beekeeping (a) and age of respondents (b)

2.2. Level of studies and beekeepers' motivation

Figure 3a gives the picture of the percentage of respondents with secondary education, lower in 2019 (28%) compared to 2023 (51.1%) and, as a result, the percentage of respondents with university education was higher in 2019 (70%), compared to 2023 (48.9%), but the proportion of respondents with postgraduate education was relatively similar in the two periods (11.8% in 2019 vs. 10.8% in 2023). Interestingly, the structure of the respondents regarding the motivation to practice beekeeping (Figure 3b), a question with several possible answers, was very similar in the two periods, except for the interest in environmental protection, which registered an increasing trend in the last period (2022/2023). It is noted that the majority of beekeepers practices beekeeping as a hobby (77.9% - 2019 vs 75.9% - 2023), for economic reasons (44.2% - 2019 vs 41.7% - 2023) and because it is an activity that gives them meaning in life (40.0% - 2019 vs 38.1% - 2023). "Family tradition" is an important reason for practicing beekeeping (around 25%), while "my profession" reason has only around 12%, and reconversion is quantified at around 4.5% of respondents.



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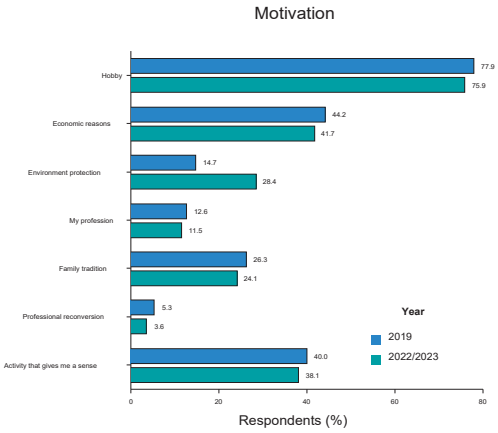


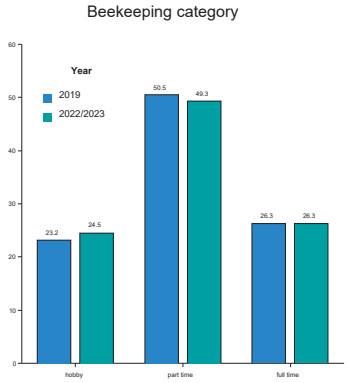
(b)

Figure 3. The structure of respondents (%) regarding the level of studies (a) and their motivation in practicing beekeeping (b) in 2019 as compared with 2022/2023

2.3. Beekeeping category and the type of hive

Regarding the category of beekeeping practiced by the respondent beekeepers, an extremely similar structure of respondents can be noticed in both study periods (Figure 4a) - 2019 vs 2022/2023: approximately 26% - full time, 50% - part time, 24% - hobby.

With regard on the type of hive used (based on the type of frame used: Dadant, Romanian multi-storey hive, mixed or other type) an extremely similar structure of respondents can also be noticed (Figure 4b) between the two periods (on average approximately 75.85%, 15.45%, 6.35%, respectively 2.3 %).



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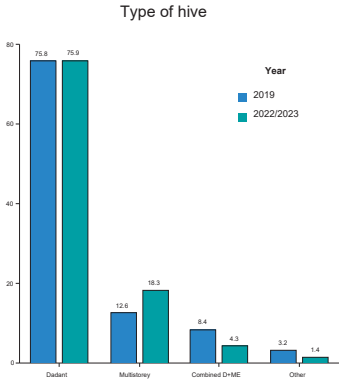


(b)

Figure 4. The structure of respondents (%) regarding the beekeeping category (a) and the type of hive used (b) (%) in 2019 as compared with 2022/2023

2.4. The size of the apiary and migratory beekeeping.

Regarding the size of the apiaries, by the application of General Linear Models (GLM), a normal probability of data was obtained throughout the period 2014-2023 (Shapiro-Wilk, Anderson-Darling tests), with significant differences between the three categories of apiaries (Table 2) as well as some variations between the structure of each period and different data sets.

If compared the data from two surveys (2016/2017 and 2022/2023) when the majority of respondents (68.7%) was recorded, significant differences were registered between all categories.

Table 2. Short descriptive statistics and multi-comparison test (Tukey-Kramer) on the structure of respondents (%) regarding the apiaries' size in the period 2014-2023

Size of the apiary	2014-2023*[1] Ave (%)	2014-2023*[2] Ave (%)	2014-2023*[1] C.I. 95%	2014-2023*[1] P-values	2016/2017 vs 2022/2023*[1] Ave (%)
Small (1-50 colonies)	31.7	22.54	25.4-38.0	0.0015 (L-S)	34.4
Medium (51-150 colonies)	55.5	64.76	49.2-61.9	0.0002 (M-S)	53.2
Large (Over 150 colonies)	12.7	12.70	6.4-19	0.0000 (L-M)	12.4

*Data reported to total respondents by [1]validated questionnaires for general data and by [2]validated questionnaires for colony losses reporting (see Table 1).

The Figure 5 shows the structure of beekeepers who practice migratory beekeeping. Taking into account that the average percentage of respondents (56.0%) for the whole period of time is relatively close to the average value of respondents' number (60.07%) for 2016/2017 and 2022/2023 surveys, when the highest percentage of completing the questionnaire was recorded, it is expected that this result will be a good indication of the real situation in the country.

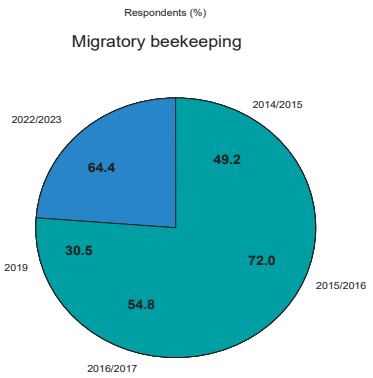


Figure 5. The structure of respondents' (%) regarding the migratory beekeeping in 2014-2023 period

3. Data regarding colony losses

3.1. Colony losses by overwinter mortality

The comparisons were made between data sets collected and validated in 2014/2015, 2015/2016, 2016/2017 and 2022/2023 (Table 1) surveys, totalising 315 questionnaires.

As shown in Table 3, it can be observed that the lowest honeybee colony mortality rate (Ave = 5.04%) was recorded in 2014/2015 and the highest (Ave = 17.04%) was recorded in 2022/2023 - interview and onsite data. It is also found that the rate of mortality assessed on the basis of the telephone interview is higher (Ave = 17.79%) than that calculated on the onsite (printed) questionnaires (Ave = 16.04%), the difference being probably due to the number of bee colonies, to the number of responding beekeepers, but also to the coverage degree of the country.

More than this, with the occasion of interview, the beekeepers were asked to offer information about the number of colonies in August 2022 in order to assess the colony mortality rate in autumn. The results show that a number of 7338 colonies were registered in August, with an average colony mortality rate of 7.82% [95% CI: 3.1-9.9] in autumn, which increases the total colony loss rate by mortality to 24.23% [95% CI: 18.5-29.4].

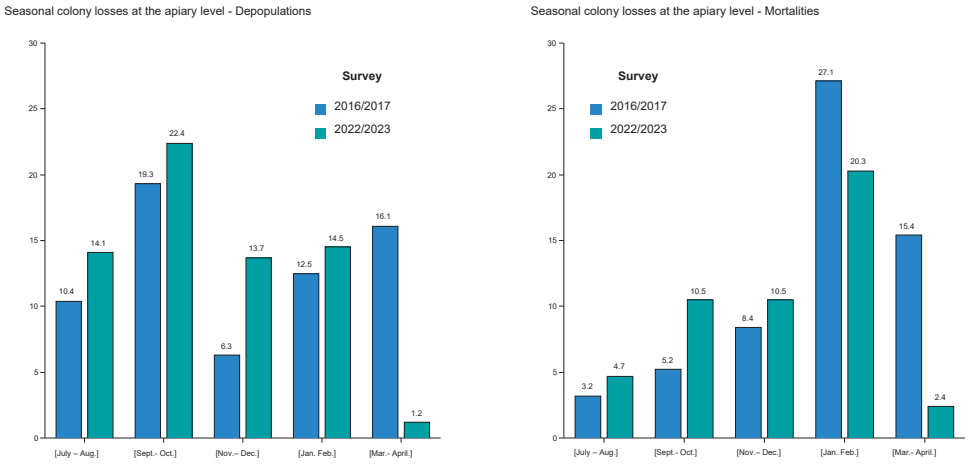
Table 3. The overwinter mortality rates of honeybee colonies in different surveys

Survey	Participated counties (n)	Validated questionnaires (n)	Registered colonies in autumn (n)	Registered colonies in spring (n)	Mortality of honeybee colonies over the winter (Ave, %) [95% CI]
2022/2023 (interview)	21	71	6570	5401	17.79 [14.4-25.2]
2022/2023 (onsite)	7	62	4969	4172	16.04 [8.2-19.7]
2022/2023 (total)	23	133	11539	9573	17.04 [13.2-21.0]
2016/2017 (onsite)	9	66	6145	5673	7.68 [5.7-14.3]
2015/2016 (onsite)	8	50	3848	3654	5.04 [3.1-10.9]
2014/2015 (onsite)	19	67	5739	5305	7.56 [4.3-10.3]
Total	35	315	27271	24205	11.24[9.8-14.1]

3.2. The incidence of colony losses

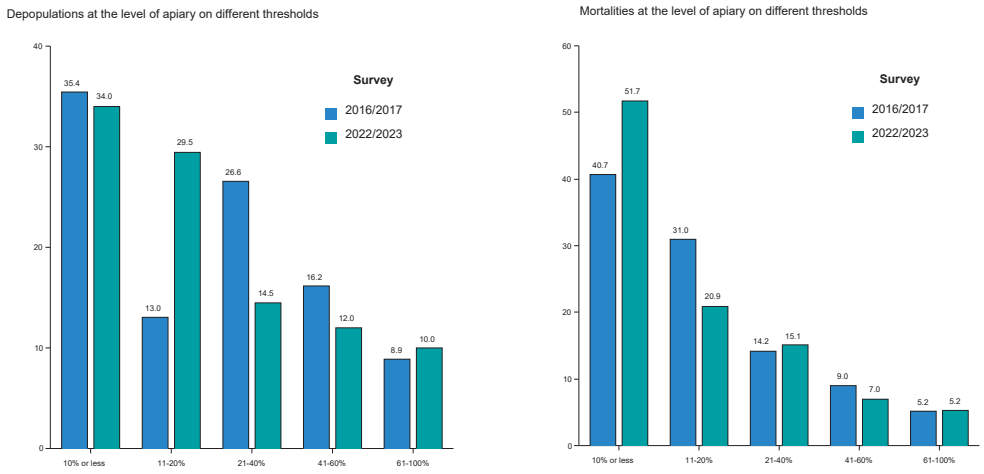
As can be seen from Table 4, the majority of beekeepers, on average 85.1% (min. 65.3% in 2015/2016, max. 93.2% in 2022/2023) declared that they had losses of honeybee colonies through depopulations and/or mortalities. However, through the subsequent questions, quantifying these losses on validated questionnaires, on average 56.5% of the responding beekeepers registered depopulations, located in one of the thresholds above 10% (min. 46.9% in 2015/2016, max. 69.7% in 2016/2017), while 32.7% of the surveyed beekeepers recorded colonies mortality above 10% (min. 18.4% in 2015/2016, max. 49.6% in 2022/2023). As regarding the evaluation of depopulation and mortality on various thresholds and months of the monitored period of the year (from July last season until April next year), the situation of questionnaires from the period 2016/2017 was compared with that of 2022/2023 when the largest number of questionnaires was collected (228, respectively 278).

The structure of respondents (%), depicted in Figures 6a and 6b, shows that the incidence of depopulations over 10% in 2016/2017 period was higher at the beginning of the monitored period (Sept./Oct.), but also at the end of it (Mar./Apr.), while the incidence of mortalities was higher during the winter period and early spring (Jan./Feb. and Mar./Apr.). In 2022/2023 survey, the incidence of depopulations was again higher in autumn (Sept./Oct.) as compared with early spring, while the mortalities were higher in winter (Jan./Feb.) and it is possible that they continued in March-April as the overwinter mortality rate was higher in 2023 as compared with 2017. It follows that the incidence of depopulations and mortalities was continuous, with the peak in September-October for depopulations and in January-February for mortalities. The overall incidence of depopulations and mortalities, using both, online and onsite questionnaires, on different thresholds, in 2016/2017 - 2022/2023 surveys, is presented in Figures 7a and b, but some differences in the collected data were registered in each survey for the whole period (2014-2023).



(a) (b)

Figure 6. The structure of respondents (%) who reported colony depopulations and mortalities over 10% at the level of the apiary, between July last season to April next season - a comparative situation 2016/2017 - 2022/2023. Note: Data for March-April 2023 is not accurate as a great part of the questionnaires was collected in February 2023



(a) (b)

Figure 7. The structure of respondents who reported colony depopulations and mortalities at the level of the apiary, on different thresholds, a comparative situation 2016/2017 - 2022/2023 from online and onsite surveys

Table 4. The incidence of colony losses in the last years in terms of beekeepers' percentage affected by different colony losses as reported to the total number of validated questionnaires

Survey	Beekeepers who declared colony losses as depopulation or/and mortalities		Beekeepers who declared depopulations over 10%		Beekeepers who declared mortalities over 10%	
	n	%	n	%	n	%
2022/2023 (interview)	66	93.0	44	62.0	39	54.9
2022/2023 (onsite)	58	93.5	33	53.2	27	43.5
2022/2023 (total)	124	93.2	77	57.9	66	49.6
2016/2017 (onsite)	58	87.9	46	69.7	13	19.7
2015/2016 (onsite)	32	65.3	23	46.9	9	18.4
2014/2015 (onsite)	54	80.6	32	47.8	15	22.4
Total	268	85.1	178	56.5	103	32.7

3.3. The possible causes of colony losses

Figure 8 presents a summary of data obtained by different surveys, regarding the most important reasons appreciated by beekeepers for recording colony losses. A number of 13 possible multiple causes were listed, with the possibility of registering a possible cause not listed under "others".

From the graphic representation, but also from the average recorded over the entire period regarding the number of respondents, neonicotinoid treatments at sunflower (50.5%), at rapeseed (38.6%) and in general those applied at the time of blooming (34.8%), together with varroosis (37.8%) are considered by beekeepers, major causes of colony losses.

Another important cause is represented by the quality of nutrition (34.1%) before entering the winter. Other possible causes were listed such as other diseases or pests (chalkbrood, American foulbrood, wasp attack - 4.8%), the lack of treatments with specific controlling products (5.7%), insufficient food storages for winter (9.4%) as well as of poor quality (7.1%), or a number of other causes mentioned by beekeepers (16.8%) such as: weather conditions, lack of honeyflows, lack of queens, theft, quality of artificial honeycombs or the humidity in the hives.

By collecting information on different factors in subsequent questions, there were registered valuable data which to be further analysed.

Using the Spearman correlation, a heat map (Figure 9) was produced to highlight the factors which are positively or negatively correlated each other or with the honeybee colony losses.

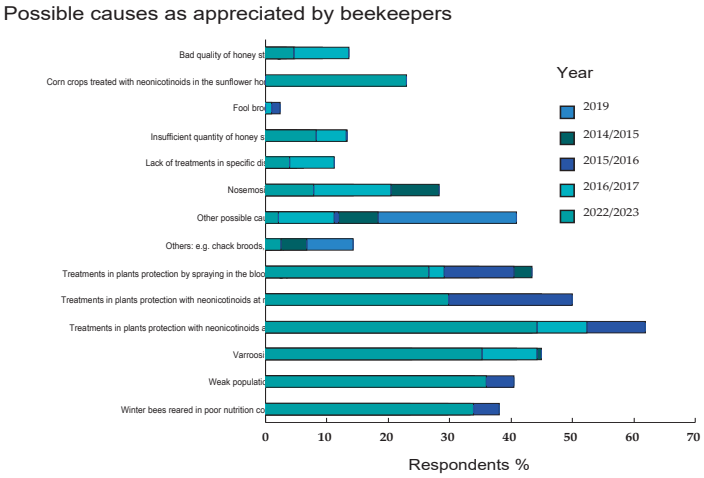


Figure 8. The structure of respondents (%) regarding the possible factors for colony losses registered in 2014-2023 period

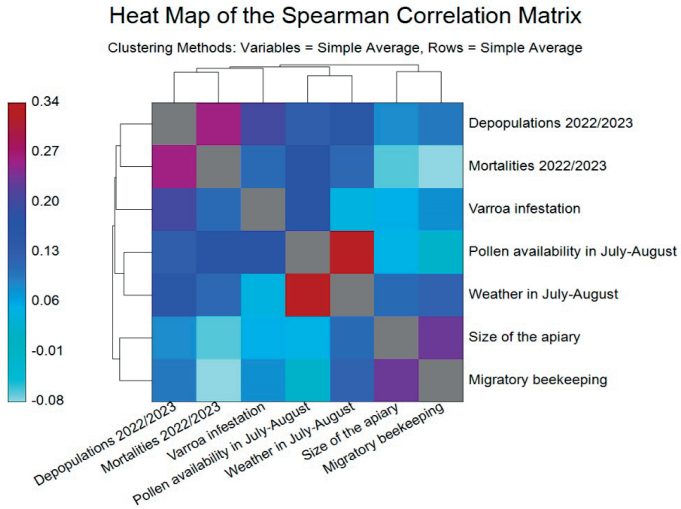


Figure 9. The Spearman correlations between different factors and colony losses expressed as depopulations and mortalities registered in the last survey - 2022/2023 (258 respondents)

DISCUSSIONS

Questionnaires are an important tool in beekeeping research, as they provide valuable information about this activity field. Completion depends on the degree of promotion of the questionnaire through social media or onsite, but also on the direct cooperation with beekeepers (Brodschneider et al., 2022). As the literature shows, the coverage degree of a country and response rate vary widely not only between countries and years (Gray et al., 2023), but also at national level, as resulted from our data (Figure 1). The number of responding beekeepers per survey in the present research is relatively low as compared with other countries that participated in COLOSS surveys in the same period 2014-2023 (Gray et al., 2023; Gray et al., 2020; Gray et al., 2019; Brodschneider et al., 2018; van der Zee et al., 2016; van der Zee et al., 2014). However, a higher rate of answers in online format was recorded in the periods 2016-2017 and 2022-2023 as compared with other data from Romania (Gray et al., 2023). Using more ways for distribution (online, e-mails, onsite) led, as expected, to increase the

rate of completing, so the general view on the obtained results was improved, too. This was particularly noticed in the comparisons regarding general data on beekeeping, where younger beekeepers with less experience but with a higher level of studies were more responsive in online media (Figure 2a and b, Figure 3a). Surprisingly, the structure of respondents regarding the motivation to practice beekeeping, the beekeeping category and the type of hive used remains generally the same between the two data sets (Figure 3b, Figure 4a and b). Even if many similarities were registered, one can remark, by comparisons between these years (Figure 3b), that beekeepers are more and more engaged to practice beekeeping for reasons related to environment protection.

Regarding the size of the apiaries in Romania, data show that, in average for the whole period 2014-2023, the majority of beekeepers (55.5%) own "medium size" apiaries (51-150 colonies), being followed by "small" category (< 50 colonies) and "large" (> 150) apiaries. The data averages obtained for the whole period (Table 2) offer a good image that could be extrapolated to the total number of beekeepers in Romania. These data are different from those reported in the last published COLOSS survey in 2019/2020 (Gray et al., 2023), which show that the most part of responding beekeepers (90.2%) in 37 countries (26 countries belonging to EU) are part of the "small size" category of apiary.

The obtained answers at national level in all questionnaires show that migratory beekeeping is practiced in average by 56% of respondents, with greater variations between the years when smaller sets of answers (under 100) were received, but the total average being very similar with the years where a greater number of answers was collected. These data are contrasting with the results obtained in COLOSS questionnaires, where, overall, only 18.3% of respondents reported that they practice migratory beekeeping (Gray et al., 2023).

Regarding colony losses by overwinter mortalities, the results (Table 3) show a higher rate of colony losses registered in the last year (17.04%), as average of respondents' number between onsite survey (16.04%) and interview (17.79%). This loss rate is higher as compared with the obtained ones in previous years at national level (under 10%) and in 2019/2020 Coloss survey for Romania (15%) (Gray et al., 2023), but relatively similar with the overall winter loss rate at the level of EU countries (17.7%), this being ranked in the middle category of colony loss rates. When these losses where quantified as incidence of colony losses on different thresholds (Table 4), 56.5% of respondents declared depopulations over 10% and 32.7% reported mortality over 10% on the all-validated questionnaires. The obtained data highlight also the variations of colony losses between different months. By comparing data form 2016/2017 and 2022/2023 (Figure 6) some critical periods were observed, as for example September-October for depopulations and January-February for mortalities (Figure 7). That is another reason why, as a case study, we have run the interview for the last survey, in order to find out also the autumnal colony mortalities rate, which was recorded at 7.82%, increasing the autumn-winter losses at a very significant level of 24.23%. These results come to complete the image of colony losses by mortality and depopulations in different period of the year, as a very complex phenomenon, with multiple causes, whose effects could overlap or cumulate (Gregorc, 2020; Hristov et al., 2020; Goulson et al., 2015).

Generally, the colony losses by depopulation are difficult to be quantified and understood because they are often a result of sublethal effects of different factors, as different chemicals who accumulate in the hive, pathogens or nutritional status (Martinello et al., 2020; Căuia et al., 2020; Cousin et al., 2019). The quantification of these type of losses in the same time with the identification of prevalent causing factors could contribute to a better awareness and monitoring in beekeeping management. With respect to the perceived causes of colony losses, the sets of answers show that the most part of respondents considers that colony losses are caused firstly by phytosanitary treatments at different crops, especially at sunflower and by varroosis (with the associated viruses), as well as by poor nutrition (Figure 8). These factors, singles or combined, as the mentioned literature shows, conduct to weaker colonies with low longevity honeybees in autumn and during the wintering season.

The questionnaire included also different questions on varroosis or nutrition (e.g. pollen and nectar flow availability in the late part of summer, food storage for winter), as well as questions to collect indirect information about nutrition (brood rearing and drone eviction in summer) which worth to be insighted by further analyses to predict the colony losses (Johannesen et al., 2022). They show a fluctuating picture from year to year, with difficulties in providing protein and carbohydrates the colonies need for daily requirements and winter storages. However, using a heat map for correlations matrix (Figure 9) between different factors and colony losses, one can notice that some factors are highly significant correlated (depopulations with mortalities, pollen availability with weather in July-August, migratory beekeeping with size of the apiary), some factors are middle values correlated (varroosis with depopulations, pollen with mortalities) and other factors are weakly correlated (mortalities with migratory beekeeping and size of the apiary).

It is important here to note that some information collected in the survey about the quality of last honey flows show that almost 2/3 of respondents rely on sunflower, this crop being extremely important in Romania for its impact on honey production (Ion et al., 2008; Ion et al., 2008; Ion et al., 2007; Stefan et al., 2008), as well as on the quantity and quality of honey storages for winter which affect the wealth of honeybees in the fall-winter season.

In the last period, around 10% of respondents reported a lack of the necessary honey flows to sustain the critical periods in the late season when the winter honeybees are reared, this being probably connected with climate changes. Regarding the weather conditions, 2022 year was appreciated by the responding beekeepers as the driest year in the monitored period (2014-2022), and this situation correspond to the data published by the Romanian National Meteorological Administration, which shows that 2022 was the driest year in the last 10 years and the third warmest year in the history of meteorological measurements in Romania (1900-2022), the average annual temperature being 11.77°C, with a thermal deviation of 1.55°C compared to the average of the period 1981-2010. In fact, six years in the surveyed period (2014, 2015, 2018, 2019, 2020, 2022) were also among the warmest 5 years from 1900-2022 in Romania, with 2019 the warmest year, and the 2012-2022 interval represents the warmest period in the history of measurements, a fact that can have important repercussions on honey flora and beekeeping. Weak population for winter and wintering bees reared in poor nutrition following unfavourable weather conditions were between the biggest concerns of respondents (Figure 8).

The reported here colony losses data and the possible factors affecting colony welfare could help different stakeholders to prioritize further decisions and researches to prevent these phenomena and to support beekeepers to counteract colony losses and adapt to new challenges related to climate change and other risk factors.

CONCLUSIONS

It is for the first time that a temporal situation on honeybee colony losses in Romania is presented. The obtained results on general beekeeping data and colony losses, both depopulations and mortalities, show a very dynamic and complex situation, which requires further evaluations. Using regularly a standardised, complex questionnaire, adapted to local conditions and requirements, will ensure the obtaining of useful and comparable data at national and international level.

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