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Evaluation of the honey bee colonies weight gain during the intensive foraging period

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Abstract. Beekeeping in Latvia has a long tradition and it is a classical branch of agriculture. In Latvia, there is no traditional beekeeping region, and beekeeping is performed in all regions. Honey yield is influenced by various factors - variety of crops (nectar plants) around the apiary, man-made changes in land/forests (deforestation), climate change, beekeepers' actions, etc. Application of information and communication technologies (ICT) in the field of beekeeping can bring benefits to the beekeepers. To be more specific, continuous remote monitoring of certain bee colony parameters can improve beekeeper's apiary management, by informing timely about the nectar flow (or even provide information on bee colony states, e.g., swarming). In such a way, beekeepers can plan their next actions - prepare supers or even choose to move the apiary to a different geographical location. Within this research, weight gain of the ten honey bee colonies was remotely monitored and analysed during two-week period at the beginning of the summer 2021 in Vecauce, Latvia, using the precision beekeeping approach. This monitoring period corresponded to intensive flowering of the winter rapeseed and field beans. Colonies were equipped with the automatic scales. In addition, colony and environmental temperature was monitored. Measurements were taken every thirty minutes. Analysing the obtained data, weight increase can be observed in all colonies, from 17 to 48 kg. As well, based on weight data, swarming event can be identified. Constant monitoring of weight change can also help to identify daily patterns in honey bee activity.

Key words: precision beekeeping, weight monitoring, foraging activity, honey bees, winter rapeseed, field beans.

INTRODUCTION

According to (Crane, 1990), only 16% of the world's flowering plant species contribute to honey bees (*Apis* spp.) as food sources. Moreover, not all bee plants are equally important to bees and honey production (Adgaba et al., 2017). This indicates that, for every local geographical region, there are very few important honey source plants. Based on comprehensive studies, it was possible to estimate the honey production potentials of some major honey source plants: such as *Trifolium pratense* L. (red clover) (883 kg of honey ha^{-1} flowering season; Szabo & Najda, 1985); *Asclepias syriaca* L. (milkweed) (500–600 kg honey ha^{-1} per flowering season; Zsidei, 1993) and *Phacelia tanacetifolia* Benth (60–360 kg honey ha^{-1} per flowering season; Nagy, 2002). Average honey production per hive is 20 kg throughout the world (Kizilaslan & Kizilaslan, 2007).

Beekeeping in Latvia is a long-standing agricultural industry developing rapidly along with other industries. The only honey bee species used in Latvian beekeeping is *Apis mellifera* (Zacepins et al., 2021).

Latvia is located in a mixed forest area, which occupies 48.21% of the entire territory, while 35.44% is arable land, meadows, pastures and gardens, 1.61% - shrubs and 3.34% - marshes[1], but the remaining areas (land under waters, roads, etc.) are not suitable for beekeeping. The natural foraging base does not provide the honey yield evenly throughout the whole season, thus the average honey yield in Latvia is about 20 kg per colony. In some periods, at the end of May and in the second half of summer, natural yield decreases (Liepniece, 2015).

A very rich composition of plants is found in Latvia, therefore bees have an opportunity to bring very diverse nectar into their hive (Lapina, 2016). One of the important cultivated plants for the honey bees in Latvia is rape (*Brassica napus* L.). This is a 60–130 cm high annual herbaceous plant belonging to the family of cruciferous plants (Brassicaceae). Rape is a good nectar crop with a high yield. In rape flowers, nectar is released continuously, so bees can visit one flower repeatedly (Liepniece, 2015). Oilseed rape honey crystallizes very rapidly after the honey extraction, as there is more glucose than fructose in the plant nectar, which influences the fructose/glucose ratio in honey (Bertazzini & Forlani, 2016). This honey becomes almost white, as there are practically no minerals. Some other field crops important for honey bees also should be mentioned. For instance, two legumes (Fabaceae) species - faba bean (*Vicia faba* L.) and winter vetch (*Vicia villosa* Roth) - are relatively popular in Latvia.

Honey production of the colonies is under the effect of many factors, such as the performance of the bee queen, colony strength and climate and pasture conditions (Genç & Aksov, 1993). A high honey yield can be obtained by having strong colonies at the beginning of honey flow. Honey yield can also be affected by the professionality of the beekeepers and colony health status, as well selection of the apiary location is important (Komasilova et al., 2020).

Nowadays, the evaluation of a honey bee colony foraging activity can be done remotely and continuously, thanks to achievements in the precision beekeeping. Precision beekeeping allows to remotely monitor individual bee colonies using the information and communication technologies (Zacepins, 2015). One of the colony parameters that is important for the beekeepers is its weight. Weight dynamics can provide the beekeeper with essential information on several important colony events (Buchmann & Thoenes, 1990; Meikle et al., 2006, Komasilovs et al., 2019). Colony weight should be monitored in order to: identify the beginning and the end of nectar flow or daily gain in nectar stores (Meikle et al., 2008; Okada et al., 2012; Human & Brodschneider, 2013); monitor food consumption during passive period (Seeley & Visscher, 1985; Stalidzans et al., 2017); to detect swarming event (Meikle et al., 2008; Linton, 2012). The application of colony

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[1] The State Land Service (https://www.vzd.gov.lv/lv/zemes-sadalijums-zemes-lietosanas-veidos) [last accessed: 15.12.2021]

scales is well-established in the beekeeping industry, as they are used to determine the gains and losses of the hive mass and, in this way, indirectly indicate an increase or decrease in honey growth in a bee colony (Bratek & Dziurdzia, 2021).

Precision beekeeping in Latvia also started to be a part of the beekeeping practice, thus the benefits of such an approach should be presented to the beekeeper community (Zacepins et al., 2021).

The main aim of this research was to monitor and analyse the honey bee colonies weight dynamics during the oilseed winter rape and beans flowering period in one location in Latvia using the automated bee colony scales.

MATERIALS AND METHODS

Location description

Experiment and measurements were carried out at LLU (Latvia University of Life Sciences and Technologies) apiary (Fig. 1), located in Vecauce, Latvia (GPS coordinates: 56.*46753585940729*, 22.88788600517433) during spring-summer period 2021 (from 07.05.2021 until 07.09.2021). For this publication, data from 04.06.2021 until 21.06.2021 was analysed, as this period corresponds to the intensive winter rapeseed, faba beans and winter vetch flowering period.

Within a radius of three kilometres, various habitats were found around the studied *apiary*: agricultural land, forests, small town, roads, railways, small rivers and ditches. Most of this area was occupied by agricultural land, which was mostly used for various arable crop growing.

Figure 1. Honey bee apiary in Vecauce, Latvia.

Among these, winter oilseed rape was grown in the fields with a total area of 182.79 ha, faba beans - 106.47 ha and winter vetch - 25.99 ha (Fig. 2).

Apiary description

Ten honey bee (*Apis mellifera*) colonies from the 40 colony apiary were chosen (based on a beekeeper's suggestion) for the remote monitoring. Colonies were placed in Latvian design type hives made from wood with frame dimensions of 300 mm (height) and 435 mm (width) for brood, and frames with dimensions of 146.5 mm (height) and 435 mm (width) for honey. All hives were put in the same location in an open environment with the distance of at least 5 m between hives in a one column and 3.5–4.5 m between hives in a one row. Hive volume for the brood is 81.7 L, but if additional honey frames (twelve frames) are added then volume increase to 120 L. Weight and temperature of the colonies were continuously measured with the time interval of 30 minutes between two measurements by the automated bee colony scales (including inside thermometer), and in addition environmental temperature was monitored. For some analysis (Table 2) author's used average values per day to decrease the potential error if using one value at exact moment.

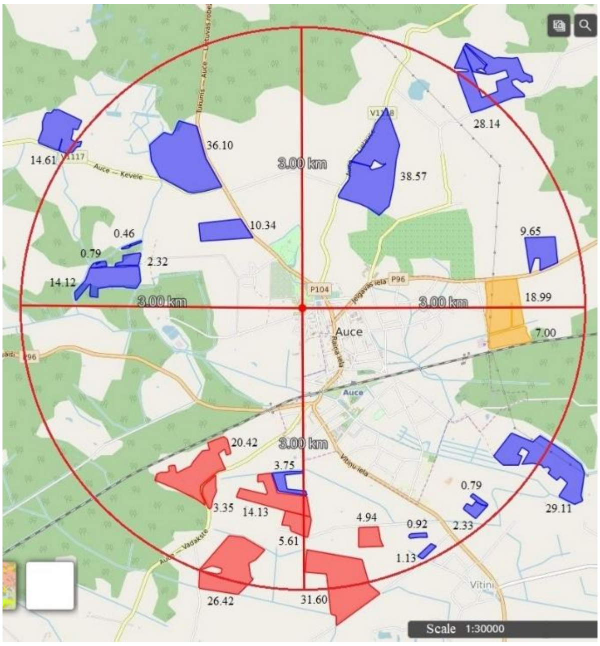

Figure 2. Topographic map of Vecauce area. The center of the red circle indicates the apiary that was studied. The red circle delimits the area within a radius of 3 km around the apiary. Fields in which winter rape, faba beans and winter vetch were grown in 2021 are painted in violet, red and yellow, respectively. The numbers next to these fields indicate their area in hectares.

Monitoring device

All colonies were equipped with bee colony monitoring system based on the ESP8266 microchip inspired by the monitoring system developed within the SAMS project (Wakjira et al., 2021). For weight monitoring, a single-point load cell Bosche H30A was used. For the bee colony temperature monitoring DS18S20 1-Wire® sensors were used. Load cell accuracy and precision were empirically evaluated by (Kviesis et al., 2020). The precision of the scale measurement system (single point load cell H30A together with the 24-bit HX711 A/D converter) was observed to be around 10 g.

One temperature sensor (Dallas DS18S20) per colony was installed inside the hive above the hive body (brood frames) as suggested by (Stalidzans & Berzonis, 2013).

The monitoring system was powered by a Sony Li-ion 18650 3.7 V 3120 mAh battery. Data about the bee colony, battery charging status and wi-fi signal were collected every 30 minutes and sent to the remote cloud platform. The screenshot below (Fig. 3) demonstrates how the summary of the colony monitoring was shown to the beekeeper on the cloud platform in real-time:

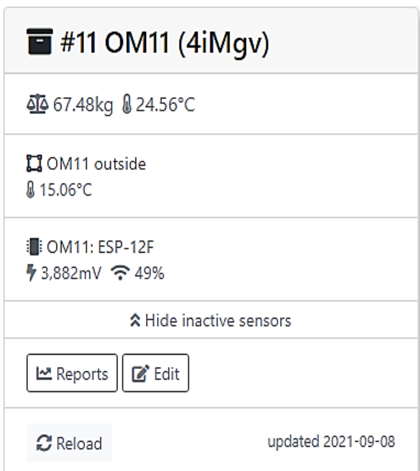

Figure 3. Data demonstration to the end users.

For the internet connection, local Wi-Fi network was used. Distance from the Wi-Fi router to the monitoring nodes was around 70 m, and the signal strength was considered as below average. To prevent data loss due to the Wi-Fi router failure (or bad signal strength caused by weather or other obstacles), each monitoring device was equipped with an SD card.

Description of environmental parameters

Weather conditions during the observation period were suitable for successful foraging activities (see Table 1). Data about environmental parameters were collected from nearest public weather station from www.meteo.lv. Table below summarises the average values for temperature, humidity, wind and rain during the observation period.

Based on the literature data (Komasilova et al., 2021) the observed conditions are considered as great for the foraging process. Ideal conditions are considered when temperature is between 20 °C and 30 °C, humidity between 60% and 80%, wind speed less than 5 m s^{-1}, and there is no rain.

Table 1. Meteorological data during the observation period

Date	Average values (time period: 5:00–22:00)			
	Air temperature, °C	Humidity, %	Wind, m s^{-1}	Rain, mm
04.06.2021	18.38	62.33	1.88	0.00
05.06.2021	19.18	57.47	3.72	0.00
06.06.2021	19.56	55.06	3.25	0.00
07.06.2021	20.66	57.00	4.03	0.00
08.06.2021	19.12	68.75	3.46	0.00
09.06.2021	18.98	68.89	2.98	0.00
10.06.2021	19.51	66.72	2.78	0.00
11.06.2021	20.15	68.50	2.25	0.00
12.06.2021	16.73	84.42	3.32	2.32
13.06.2021	15.84	66.67	7.10	0.07
14.06.2021	17.40	55.25	2.97	0.00
15.06.2021	17.80	62.61	4.38	0.00
16.06.2021	18.15	55.36	2.29	0.00
17.06.2021	20.43	59.50	2.64	0.00
18.06.2021	23.58	57.44	3.19	0.00
19.06.2021	25.28	58.84	3.27	0.00
20.06.2021	26.40	62.64	3.69	0.00
21.06.2021	27.34	61.53	4.06	0.00

Pollen analysis methodology

Pollen was collected in apiary using pollen traps placed outside the beehive entrance. The beekeeper took pollen samples (400 g) from five hives every two weeks, thus these samples contained pollen collected during two-week period of time. The samples were stored in a freezer at –18 ℃ until the middle of August when they were prepared for further analysis. All samples were then divided into two parts. One part of each sample was placed in a dryer at 35 degrees and dried for 24–36 hours, then sent to Quality Services International GMbH in Germany for analysis of the botanical composition. The second part of each sample was sent frozen to the Water & Life Lab analytical laboratory in Italy to identify pesticide residues in the pollen. The botanical composition of pollen was determined using microscopy, and the pesticide residues were determined using GC/MS/MS, LC/MS/MS methods with the lowest analytical limit of 0.01 mg kg^{-1}.

RESULTS AND DISCUSSION

Time period from 04.06.2021 till 21.06.2021 was taken for the detailed analysis of the weight gain of the ten monitored bee colonies.

Table 2 and Fig. 4 below demonstrate average weight gain for all colonies. Average weight is calculated considering 30 minutes individual measurements intervals.

Table 2. Average weight per day for all colonies

Date	Average weight per date, kg									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
04.06.2021	104.53	117.78	89.58	118.08	94.72	98.28	113.02	108.02	113.76	107.12
05.06.2021	106.29	118.15	91.72	115.89	95.84	100.47	114.96	108.85	116.57	111.29
06.06.2021	107.33	126.23	90.40	121.74	96.84	98.57	121.78	114.43	121.88	116.85
07.06.2021	110.94	132.36	89.40	127.03	100.05	97.80	126.85	119.47	128.63	119.46
08.06.2021	113.47	137.80	91.57	130.44	102.13	99.89	129.54	122.25	130.79	120.93
09.06.2021	114.50	139.37	92.21	133.07	103.85	100.88	131.37	123.34	132.66	121.32
10.06.2021	115.27	140.72	93.02	134.86	105.05	101.98	132.12	124.31	134.01	121.16
11.06.2021	115.96	142.56	93.74	136.23	105.40	102.67	132.81	125.06	134.82	119.02
12.06.2021	116.64	144.82	94.98	137.66	106.76	103.78	134.29	126.07	136.59	118.48
13.06.2021	116.38	140.19	93.91	137.28	106.26	101.09	133.62	125.86	136.18	118.23
14.06.2021	116.48	138.80	90.94	138.06	106.59	99.37	133.88	126.27	136.09	117.76
15.06.2021	118.52	142.37	91.75	141.10	110.47	100.24	136.27	128.26	138.72	118.19
16.06.2021	120.59	145.86	92.95	144.22	112.39	101.66	138.75	130.51	141.70	118.91
17.06.2021	123.61	150.31	95.15	150.16	116.17	104.19	142.26	133.87	*145.84**	120.59
18.06.2021	126.90	154.32	97.82	155.09	119.91	107.41	145.99	137.40	*123.78**	123.10
19.06.2021	130.43	157.57	100.98	159.65	123.28	111.01	149.49	140.72	*114.41**	125.96
20.06.2021	134.24	160.00	104.26	163.67	125.91	114.19	152.77	143.75	117.55	128.54
21.06.2021	137.34	161.36	107.03	166.41	127.79	116.81	155.08	146.09	120.04	130.68

* On 18.06.2021 and 19.06.2021 beekeeper extracted some amount of honey from colony #9.

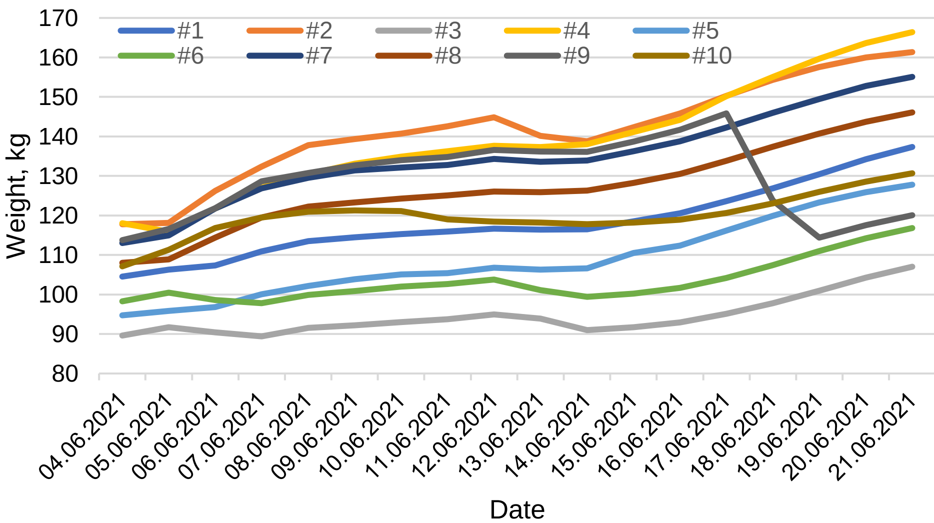

Figure 4. Weight dynamics of the monitored bee colonies

It should be emphasised that weight gain for each colony differs, which can be explained by the fact, that colonies differ in strength, and it is also dependent on the starting weight of the colony (Table 3). Starting weight included the weight of the hive itself and the bees, brood and their food storages.

Table 3. Weight change of the hives for the whole period

	Weight change of the colonies									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Starting weight, kg	104.53	117.78	89.58	118.08	94.72	98.28	113.02	108.02	113.76	107.12
End weight, kg	137.34	161.36	107.03	166.41	127.79	116.81	155.08	146.09	145.84	130.68
Change in weight, kg	32.81	43.58	17.45	48.33	33.07	18.53	42.06	38.07	32.08	23.56
Change in weight, %	31%	37%	19%	41%	35%	19%	37%	35%	28%	22%

Average weight change for all colonies - 31%.

It can be observed that the heaviest bee colony increased its initial weight by 41%, but on average bee colonies increased their weight by 31%.

Changes in the weight for all colonies per day are summarised in Table 4 below:

Table 4. Weight change of all tested colonies per day

Date	Weight change per date, kg									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
04.06.2021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05.06.2021	1.769	0.372	2.140	-2.192	1.119	2.188	1.938	0.828	2.815	4.170
06.06.2021	1.038	8.086	-1.321	5.851	1.002	-1.907	6.822	5.583	5.307	5.558
07.06.2021	3.604	6.128	-0.997	5.296	3.212	-0.769	5.073	5.044	6.753	2.608
08.06.2021	2.531	5.438	2.170	3.410	2.078	2.096	2.683	2.781	2.153	1.470
09.06.2021	1.032	1.570	0.631	2.627	1.718	0.988	1.833	1.086	1.878	0.389
10.06.2021	0.775	1.347	0.817	1.786	1.197	1.101	0.752	0.968	1.350	-0.161
11.06.2021	0.685	1.844	0.714	1.376	0.353	0.689	0.692	0.755	0.809	-2.133
12.06.2021	0.676	2.255	1.239	1.423	1.363	1.107	1.481	1.012	1.762	-0.544
13.06.2021	-0.259	-4.626	-1.063	-0.374	-0.498	-2.690	-0.673	-0.215	-0.401	-0.248
14.06.2021	0.101	-1.390	-2.971	0.779	0.328	-1.715	0.255	0.413	-0.096	-0.473
15.06.2021	2.044	3.565	0.805	3.042	3.875	0.863	2.393	1.993	2.637	0.435
16.06.2021	2.067	3.489	1.203	3.120	1.920	1.421	2.481	2.249	2.978	0.722
17.06.2021	3.025	4.458	2.204	5.935	3.784	2.536	3.511	3.356	4.139	1.676
18.06.2021	3.286	4.010	2.669	4.932	3.743	3.213	3.730	3.531	*2.514**	2.505
19.06.2021	3.533	3.243	3.155	4.564	3.366	3.603	3.495	3.320	*2.514**	2.868
20.06.2021	3.808	2.435	3.284	4.019	2.632	3.184	3.280	3.027	3.136	2.577
21.06.2021	3.102	1.355	2.768	2.741	1.884	2.622	2.316	2.347	2.494	2.142

* For colony #9 on the days, when honey was extracted, we used the average weight increase values observed on previous days.

Fig. 5 demonstrates average daily weight change of the whole group of colonies with the standard deviation. Weight change is directly related to the amount of possible foraging resources, also weather conditions has effect on the foraging activity.

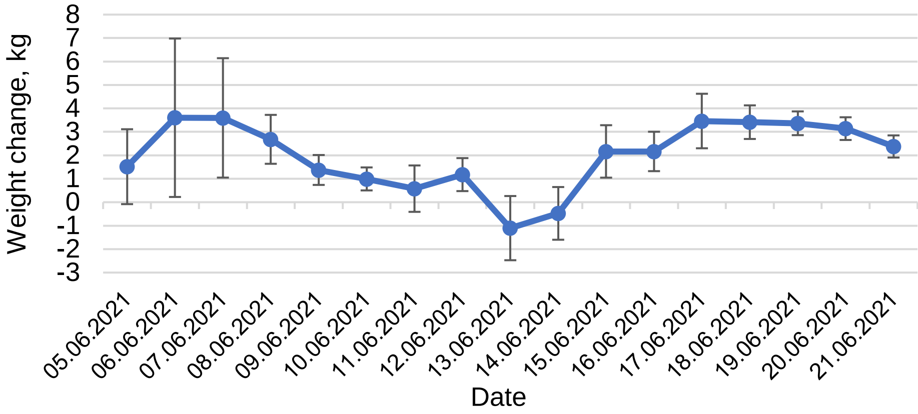

Figure 5. Average daily weight change of the whole group of colonies with the standard deviation.

Table 5. below shows maximum weight gain during one day for all colonies. It can be seen that individual bee colony can gain up to 8kg per day, depending on the foraging resources, environmental conditions and colony strength.

Table 5. Maximum weight gain per day

Max weight per day, kg									
#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
3.808	8.086	3.284	5.935	3.875	3.603	6.822	5.583	6.753	5.558

Daily routine of the bee colony

Continuous monitoring of the honey bee colony weight allows to identify daily patterns of their activity during sunny summer days. Based on the weight data, honey bee day can be split into 3 periods: nectar processing by reducing the water content during the night; flying out and foraging; coming back with collected nectar (see Fig. 6).

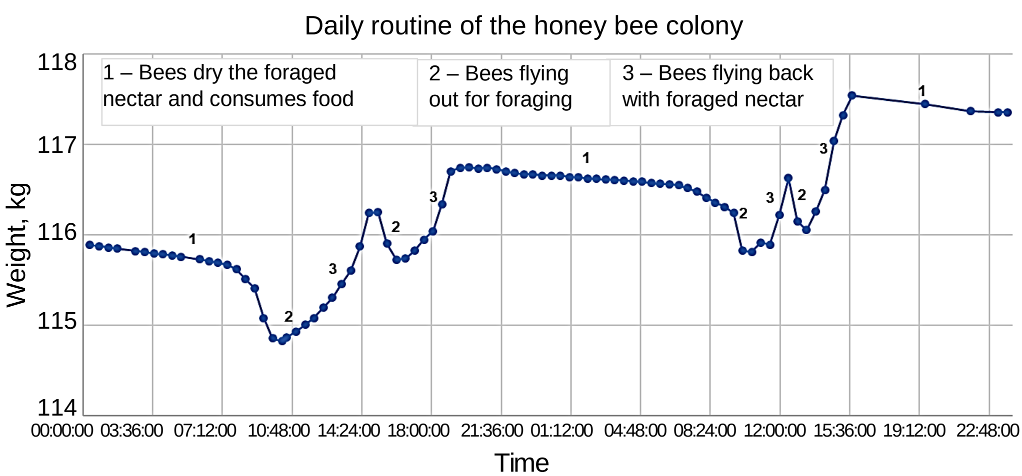

Figure 6. Daily routine of the honey bee colony.

Identification of the swarming event

In addition to the foraging activity, weight data monitoring can provide also information about the swarming event of the colony. During the observation period, one bee colony swarmed, and Fig. 7 below demonstrates this event. Suddenly #10 colony weight dropped by 2.6 kg: from 120.54 kg to 117.91 kg, and beekeeper on-site approved that the colony swarmed. This weight change during the swarming agrees with swarm weight identified by (Villa, 2004).

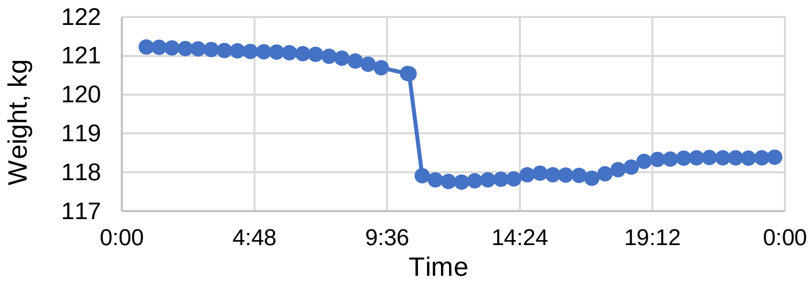

Figure 7. Weight change during the bee colony swarming event.

Effect of the rain on the foraging activity

During the foraging period weather conditions were excellent, without much precipitation. Rain was observed only on 12.06 and 13.06. Analysing bee colony average weight gain per day, it can be seen that weight decreased on 13.06 and 14.06.

This could be explained by the fact that rain affect the quality of nectar by dilution and washing out (Lawson & Rands, 2019). Authors assume that plants needed some time to produce new nectar.

Evaluation of the system battery life for the continuous monitoring

The developed bee colony monitoring system was powered by the one Sony Li-ion 18650 3.7 V 3120 mAh battery. It was evaluated that the system can operate up to 40 days with a fully charged battery. Fig. 8 below demonstrates the battery discharging dynamics during the continuous measurements with 30 minutes intervals.

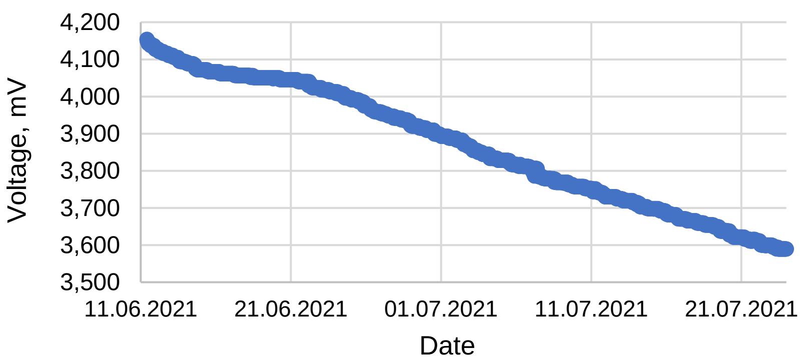

Figure 8. Battery discharge dynamics during the measurements.

Some authors report of similar system operation of 131 days with a standard deviation of 30 days (Bratek & Dziurdzia, 2021), but the measurement interval was 6 hours, not 30 minutes as done in this authors' research. However, 40 days of operation is considered to be relevant in this particular case, as beekeeper anyway visits the apiary for managemental tasks, so the change of batteries is possible.

Pollen analysis results

At the beginning of June, pollen from Brasicaceae plants predominated in the samples (58%). The bees had also collected pollen from poppies (*Papaver* spp.), dandelions (*Taraxacum* spp.), pears (*Pyrus* spp.) and other plants. During this period, the rape fields close by the apiary were in full bloom. This also explains the high proportion of pollen from Brasicaceae plants in bee yields. In the middle and second half of the month, rape had finished blooming, but field beans and vetch began to bloom. Pollen from these plants predominated in samples collected in the second half of June. Their proportion was 66%. The bees had also collected pollen from clover (*Trifolium* spp.), raspberries (*Rubus* spp.), umbellifers (Apiaceae spp.) and other plants.

Analysis of the test results for the botanical composition of the collected pollen shows that, during the period from 1st of June till 7th of June (winter rapeseed blooming period 17.05.2021-07.06.2021), bees were collecting the nectar mostly from the field where the rapeseed was grown. As pollen sample for the dates from 1st till 14th of June featured 56% of pollens containing Brassicaceae family pollens. But, in the next two weeks, field beans and winter vetch were more attractive for the bees - 66% of field bean pollens were in the sample collected from the 14th till 28th of June (field bean flowering period was from the 14th of June till 28th of June. This fact was unexpected, as usually bees choose the closest place with more intensively blooming and bright flowers (distance to rapeseed was 1.6 km closer than distance to field beans, blooms of yellow colour for bees are more attractive (Papiorek et al., 2016)).

Analysis of the plant protection product residues showed no active substrance for the field beans. For the Winter rapeseed two active substrances were found: Azoxystrobin (29 mg kg^{-1}) and Difenoconazole (0.11 mg kg^{-1}).

CONCLUSIONS

For the first time remote and continuous monitoring of the bee colony weight dynamics during the winter rapeseed and field beans flowering was performed in Latvia. The data collected, showed that if foraging conditions are good, then colony can intensively gain weight and perform active foraging process.

In conditions of the present study it was calculated for the tested period that an average of 31% weight gain was obtained.

An additional benefit of the real-time weight monitoring of the bee colonies can be the swarming event identification.

Taking into account the data obtained, by using the electronic hives, the beekeeping areas can be remotely monitored in order to evaluate accurately the honey flows at different crops, honey production or necessity of artificial feedings. Thus, the beekeepers can decide on the necessity to move the apiary to another geographical location.

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