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Comparing weight dynamics between urban and rural honey bee colonies in Latvia

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Abstract. Beekeeping is an important agricultural industry in Latvia, which has an area of 64,589 km^2 and is largely mixed forest. 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. The objective of this research was to compare the weight dynamics of colonies placed in rural and urban environments. As urban beekeeping is becoming more popular, it is important to understand whether there are enough foraging resources within the city for the bee colonies. To do this, the weight changes of ten honey bee colonies was remotely monitored and analysed during the summer period. Five colonies were located in the rural environment in Vecauce and five in the urban environment in Jelgava city. Colonies were assessed using the precision beekeeping approach and developed scale systems. It was concluded that for rural colonies in Vecauce, the main weight increase occurred in June - from 41.02 to 54.68 kg - which resulted in 94% of the total increase for the summer period. Data analysis from the urban apiary revealed that colonies increase weight during the entire monitoring period, indicating that there are foraging resources available throughout the summer period within the city.

Key words: precision beekeeping, weight monitoring, urban beekeeping, foraging activity.

INTRODUCTION

There is a growing concern about the health and number of pollinators, as insect populations are declining worldwide (Hallmann et al., 2017). Insects are responsible for pollination of up to 80% of wild plants (Ollerton et al., 2011). This fact has led to growing popularity of urban agriculture, including urban gardening and urban beekeeping.

Urban, considered also as small-scale beekeeping, is growing in many locations, like countries in North America (Ellis, 2022), major urban areas such as London, Paris, Sydney, Warsaw, Hong Kong also have a lot of city beehives (Matsuzawa & Kohsaka, 2021). This can be explained by many factors: 1) positive attitude towards the urban beekeeping in public coverage and social networks; 2) awareness about declining bee health; 3) application of pesticides in rural environments; 4) focus on biodiversity aspects. There are many recommendations on how to improve honey bee health, such as: reducing exposure to different insecticides; preventing and limiting the spread of disease and providing a greater diversity of floral resources throughout the active period of the bee colony development (Goulson et al., 2015) and placing the colonies in urban environment can be in-line with these recommendations.

There are some differences between urban and rural beekeeping. Urban beekeepers generally do not migrate their bee colonies (Ellis, 2022), but rural beekeepers in some parts of the world change apiary locations throughout the active bee colony foraging period. In Latvia the migratory beekeeping is not very common practice, only some of the beekeepers are moving their colonies around and changing the locations. Overall, 22% of the apiaries are taken out to the remote locations in Latvia (based on a beekeeper's survey in the year 2019 conducted by Latvian Beekeeping association). Among those who is placing colonies remotely, ICT solutions, like automatic scales, can help to monitor the nectar flow in the colonies to decide when to move the colonies, when the foraging activity is de-creased or the nectar flow is finished. Data about weight dynamics can provide the bee-keeper with crucial information on various important colony events (Meikle et al., 2006; Komasilovs et al., 2019).

Urban bees are potentially less exposed to pesticides as agricultural pesticides are not used in cities so much. Some authors presented results of pesticides analysis which indicated that more pesticides as well as higher concentration of them was found in rural bee samples. The analysis of pesticides shows that more polar pesticides can be found on the surface of the bodies of honey bees and more hydrophobic ones can go deep into the body. It confirms that the urban environment is more friendly for the bee colonies (Sadowska et al., 2019). But some authors states, that heavy usage of pesticides in the urban environment is a serious concern (Meftaul et al., 2020). Thus detailed investigation should be conducted per urban area samples. So, it seems, the situation can be different in different urban areas.

Urban environments can have much richer and diverse floral resources, because of the variety of plants growing within the cities (Garbuzov et al., 2015). As well, a cultivated urban environment, with its large floral biodiversity, can provide extra nutrition for bees, resulting in the production of a honey rich in nutraceutical compounds (Preti & Tarola, 2021). Honeybees living on mixed pollen showed the highest productivity, rearing more brood than bees fed monocultural pollen. The dietary quality is again reflected in longevity. Monocultural bees had a shorter life expectancy than bees nourished with mixed pollen (Szymaś & Jędruszuk, 2003; Höcherl et al., 2012).

Unfortunately, there are also some concerns about urban beekeeping, e.g., in major cities there is a huge road traffic, which is a source of dust and heavy metals, as well fuel emissions can change the odor of flowers to the extent that bees can no longer recognize them (Reitmayer et al., 2019).

There are doubts that beekeeping cannot be very productive in the cities, but we did not find any numerical results of the bee colony honey production in the city environment. Thus, the aim of this research was to identify and compare the weight dynamics of the apiary located in the urban environment (Strazdu iela, Jelgava) with the apiary located in the rural environment (Vecauce) in Latvia. Analysing the spread of urban bee-keeping in Latvia, despite the fact that beekeeping is an old and traditional branch of agriculture, there are not many examples of urban beekeeping there. It is mainly possible to see some colonies on rooftops in the capital city Riga and several other individual locations in other cities.

MATERIALS AND METHODS

Apiary location description

Experimental urban apiary was created at Latvia University of Life Sciences and Technologies (LBTU), Strazdu iela 1, Jelgava, Latvia (GPS coordinates: 56.6630, 23.7538). This apiary is located at the study centre, where some experimental green-houses, berry bushes and other garden cultures are planted. The study centre itself is located about 100 m from the main city street and various public facilities are located nearby (shopping centre, stadium, school). Five bee colonies (*Apis mellifera mellifera*) were selected for the remote observations. Colonies were placed in Latvian design type hives made from wood and in polyfoam hives.

Rural apiary was located at LBTU apiary in Vecauce, Latvia (GPS coordinates: 56.4675, 22.8878). Five bee colonies (*Apis mellifera mellifera*) were selected for the remote observations. Colonies were placed in Latvian design type hives made from wood. Within a flying radius of the bee colonies, 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, including rapeseed and beans.

Both apiaries were monitored during the summer period from 01.06 - 31.08.2022.

Fig. 1 shows apiary locations on a Latvian map:

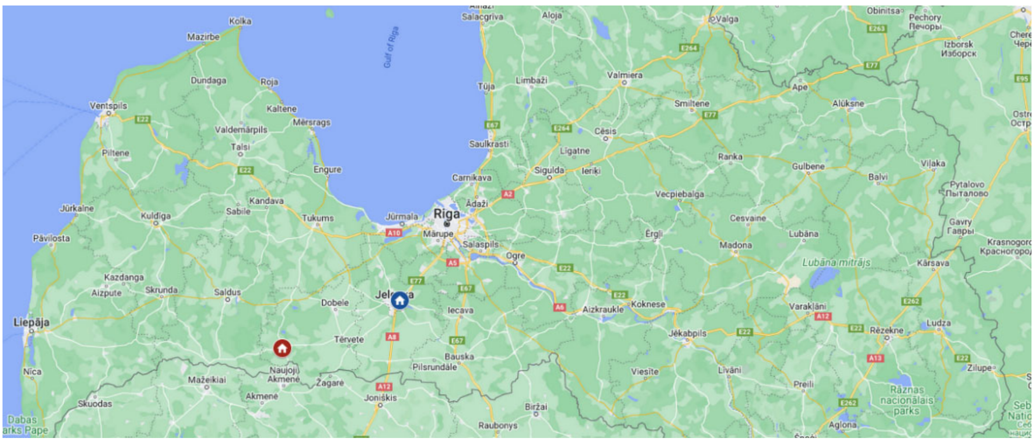

Figure 1. Location of the rural apiary (red icon) and urban apiary (blue icon) in Latvia territory.

Monitoring device

All colonies in both apiaries were equipped with a bee colony monitoring system based on the ESP8266 microchip inspired by the monitoring system developed within the SAMS project (Wakjira et al., 2021). All systems were powered by a Sony Li-ion 18650 3.7 V 3120 mAh battery. In the rural apiary a locally available WiFi router was used to transmit data to the remote server, but in the urban apiary the router was substituted with an additional communication node (powered by a solar power system) consisting of ESP32 microchip and a GSM module to transmit data via mobile network.

Each monitoring system was equipped with two Dallas DS18B20 temperature sensors and scales. For weight monitoring, a single-point load cell Bosche H30A was 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. Maximum weight, that can be measured is 200 kg. One temperature sensor (Dallas DS18B20) per colony was installed inside the hive above the brood frames as suggested by (Stalidzans & Berzonis, 2013). Second temperature sensor was placed outside the hive to monitor the environmental temperature. Weight and temperature of the colonies were continuously measured with the time interval of 30 minutes between two measurements.

Environmental parameters

Data about environmental parameters were collected from the nearest public weather station from https://www.meteo.lv/. Figure below (see Fig. 2) summarises minimal and maximal ambient temperatures, amount of precipitation and average wind speed for the monitoring period, considering values for the time period from 5:00 till 23:00 for both lo-cations. Night period is not taken into consideration, as bees are not flying at night.

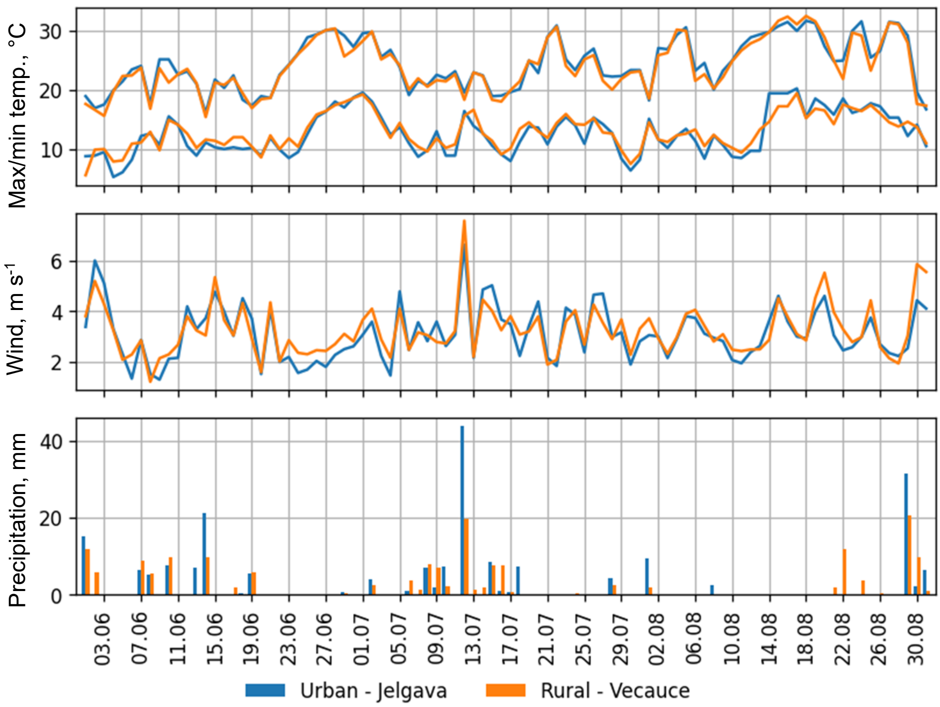

Figure 2. Weather conditions at the urban and rural apiaries during the monitoring period.

Based on (Komasilova et al., 2021) the observed conditions are considered as good for the foraging process, since the ideal conditions are defined when temperature is between 20 °C and 30 °C, wind speed less than 5 m s^{-1}, and there is no rain at the foraging site.

Weather conditions during the monitoring period were similar at both locations and almost all days of the monitoring period were suitable for bee foraging activities.

Pollen collection and analysis methodology

In addition to bee colony monitoring also pollen was collected and analysed in both apiaries. Pollen was collected using pollen traps placed outside the beehive entrance. Samples of it were collected by the beekeeper every second day from the beginning of June until the middle of August. Then the pollen 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.

RESULTS AND DISCUSSION

Purpose of this research was to compare the dynamics of weight gain by colonies located in two different environment types: urban and rural, so the weight changes are de-scribed in details below. Authors analyzed the weight change of the colonies, and not the amount of the honey produced by the colony and collected by the beekeeper, as this in-formation was not provided by the beekeepers and were not available for the detailed analysis.

Overall increase of the weight during the monitoring period

The Fig. 3 below demonstrates weight dynamics of the monitored colonies during the summer period. Period from 01.06.2022 till 31.08.2022 (92 days) was taken for the analysis. Average daily weight is calculated considering 30 minutes intervals between individual measurements. Rural colonies in Vecauce are labeled by R (R_1 to R_5) and urban colonies in Jelgava by U (U_1 to U_5).

Analyzing the data day by day, it can be observed that two periods from June 5 to June 7 and from June 24 to June 29 are clearly distinguished for Vecauce. Based on the pollen analysis, the first increase in Vecauce apiary mass dynamics in hives can be explained by cruciferous plants, mainly winter rapeseed (*Brassica napus L.*) foraging (pollen composition in the sample 83%). Part of the yield mass dynamics is also formed by nearby flowering willows (*Salix sp.*) (11%), horse-chestnuts (*Aesculus sp.*) (4%) and blackberries (*Rubus sp.*) (2%). The second significant increase in colony weight can be explained by flowering of mustard (*Sinapis sp.*) fields and wild cruciferous (*Brassicaceae*) family plants (pollen composition in the sample 34%). Part of the yield is also formed by umbellifers (*Apiaceae*) (30%), clover (*Trifolium sp.*) (18%), yarrows (*Achillea sp.*) (5%), vetch (*Vicia sp.*) (4%) and linden (*Tiliaceae*) (2%).

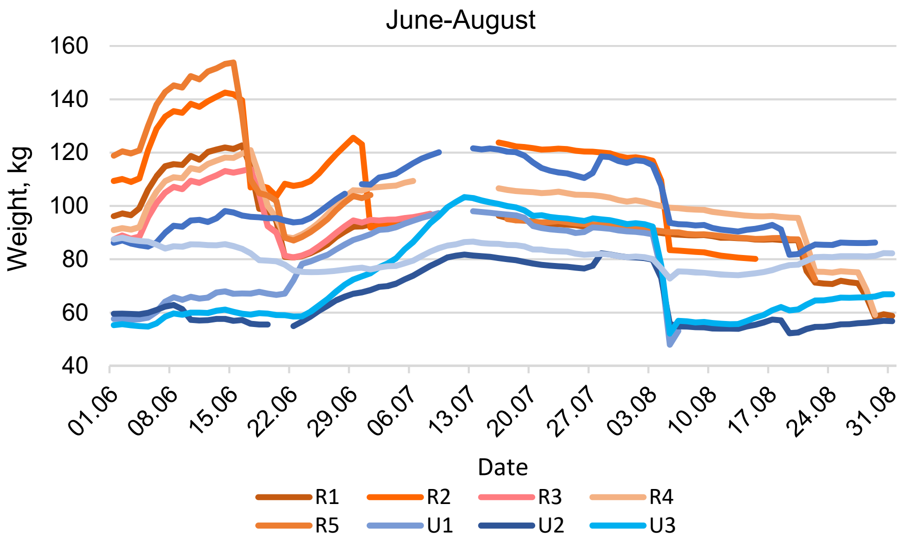

Figure 3. Dynamics of a weight change in a honeybee colonies (gaps in lines are caused by connectivity issues with Wi-Fi router in rural area, rapid weight decline indicate harvesting events).

On other days, weight gain is either very small, or generally has a negative value. Beekeepers can potentially move the rural colonies to other geographical locations, when active nectar flow is finished in the apiary, in order to increase the overall honey yield of the colonies, as well as to provide a continuous food supply for the bees. As there is a fairly even climate throughout Latvia, the use of the migratory beekeeping applies no additional stress for the bees caused by climate change, daylight changes and long traveling times. Based on the mentioned above, migratory beekeeping can be used to a large extent successfully in the territory of Latvia to provide a more diverse food base for bees, available throughout the entire period of honey collection from early spring to late summer, thereby ensuring the pollination of various crops and increasing the volumes of honey, pollen and other bee products.

For hives located in an urban environment (in Jelgava), analysing the data day by day, there are no clearly defined growth peaks, contrary to Vecauce. In general, the weight gain is quite uniform during all three months. The maximum gain per day is 3.84 kg with an average positive gain of 1.08 kg, and the number of days with a positive gain in Jelgava is 62% more than in Vecauce.

From June 5 to June 15, the weight increase in urban hives can be explained by foraging from plants of the Brassicaceae family, mainly wild weeds (e.g. field mustard (*Sinapis arvensis L.*), wild radish (*Raphanus raphanistrum L.*), wintercresses (*Barbarea sp.*)), wallflower (*Erysimum sp.*) and other cruciferous flowers, which are flowering in this time period, which made up 56% of the pollen from the obtained sample. The rest of the yield was made up of the clover genus (*Trifolium sp.*) (pollen botanical composition in the sample – 18%), the blackberry genus (*Rubus sp.*) (8%), the *Apiaceae* family (6%), the horse chestnut genus (*Aesculus sp.*) (5%) and plants of the privet genus (*Ligustrum sp.*) (3%).

From June 22 to July 3, the increase in the weight dynamics of the urban colonies can be explained by the proportion of plants of the cypress family in small gardens, urban parks, urban forest edges and natural meadows.

In the period from July 5 to July 24 weight increase is related to the active flowering of the genus Meadowsweet (*Filipendula sp.*) (botanical pollen composition in the sample 63%).

Days with a huge decrease (more than 10 kg) of the weight corresponds to honey collection events completed by the beekeeper. For the urban colonies honey collection took place on 4.08 (colonies: U_1, U_3) and 5.08 (colonies: U_1, U_2, U_3, U_4) and for rural colonies on various days: R_1 on 18.06, 21.06 and 21.08; R_2 on 17.06, 01.07, 05.08; R_3 on 19.06; R_4 on 19.06 and 22.08; R_5 on 16.06, 17.06 and 21.06.

Interruptions in data occurred due to several reasons: short-term interruptions were due to loss of a wi-fi signal and beekeepers' inspections, but long-term data interruptions were due to the low battery voltage level. These interruptions did not highly affect the whole observation period, but some periods (table cells marked in red) were excluded from the further analysis (see Table 1 below).

Table 1. Number of days with collected data for the whole observation period

Colony	R_1	R_2	R_3	R_4	R_5	U_1	U_2	U_3	U_4	U_5
June (30)	26	26	27	26	25	28	26	30	28	30
July (31)	20	18	8	21	15	27	30	31	26	31
August (31)	27	13	0	25	20	3	28	28	26	29
June-August	73	57	35	72	60	58	84	89	80	90

Overall increase of the weight during the monitoring period

Table 2 below shows the total weight gain compared to monthly weight gain. Authors define the daily weight gain of the colony as positive increase of the weight within the 24-hour period starting at midnight. To visually distinguish between high foraging months and low foraging periods colors encoding is implemented. Color scheme from red to green is used (from 0 kg increase to maximum weight gain). For the color encoding Excel Conditional Formatting was used.

Table 2. Weight gain by the honeybee colonies in kg

Colony	R_1	R_2	R_3	R_4	R_5	U_1	U_2	U_3	U_4	U_5
June-August	46.85	57.20	43.82	55.11	56.69	34.67	40.62	66.94	49.05	26.49
June	41.02	54.68	43.82	49.80	54.28	23.49	17.22	22.96	26.14	4.40
July	3.00	2.29	-	4.23	1.74	11.18	15.23	30.94	14.32	10.73
August	2.83	0.23	-	1.08	0.67	-	8.17	13.04	8.59	11.36

Honeybee colony U_5 had lower weight gain in June, because the colony swarmed, thus its development was slowed down and it was not able to fully recover after this event. This affected the overall performance of the urban apiary in June.

It should be emphasised that the weight gain for each colony differs, as colonies differ in strength, and it is also dependent on the starting weight of the colony. This starting weight included the weight of the hive box itself, weight of the bees, brood and the colony initial food storage.

Based on ANOVA single factor statistical analysis weight gains for rural and urban colonies for each month are significantly different. Calculated P-values for each month are: 0.0002 (June); 0.0146 (July); 0.0004 (August).

Table 3. below demonstrates average values for the apiaries together with the standard deviations (stdev).

Table 3. Average values for the weight gain for both apiaries

	Average values for rural colonies, kg	stdev, kg	Average values for urban colonies, kg	stdev, kg
June-August	51.93	5.51	43.56	13.83
June	48.72	5.49	22.45	3.25
July	2.81	0.93	16.48	7.44
August	1.20	0.98	10.29	2.01

Information for the weight gain by the honeybee colonies can be present in a form of a chart to provide better comparison of the honeybee colonies performance (see Fig. 4).

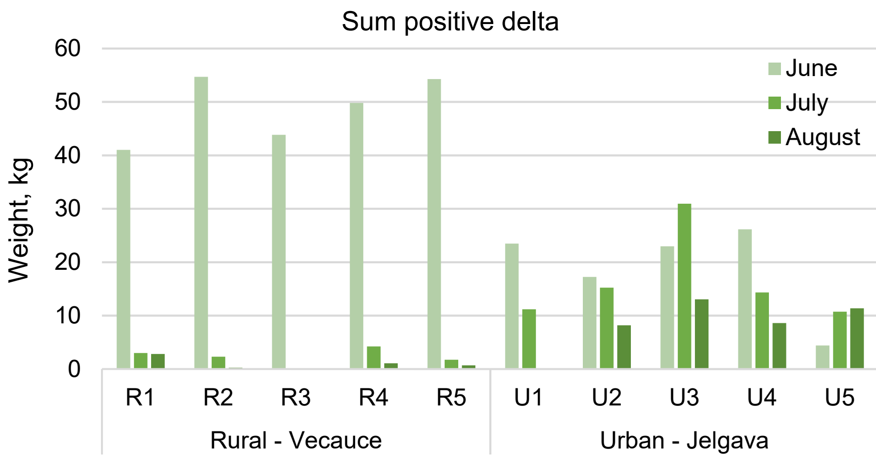

Figure 4. Weight gain of honeybee colonies in urban and rural environment.

Considering the total positive gain (delta>0) in each of the hives by months, it can be concluded that for rural colonies in Vecauce, the main weight increase occurred in June (from 41.02 to 54.68 kg), which results in 94% of the total increase for the whole summer period (June-August), while July accounts only for a 4%, and August for a 2%.

For urban colonies located in Jelgava, the following distribution of the weight gain can be observed: June accounts for a gain of 43%, July for an 38% and August for 19% of the total positive weight gain.

Detailed weight dynamics analysis per days

Analysing the number of days with a positive weight gain in the hives, it can be not-ed that for the rural apiary in Vecauce the majority of days with the positive gain (73.9% on average) are in June, 18.6% in July and 14% in August. While for the urban apiary in Jelgava the distribution of days with a positive increase for three months has the lower distribution and averages at 41.1% for June, 31.2% for July and 34.6% for August (see Fig. 5).

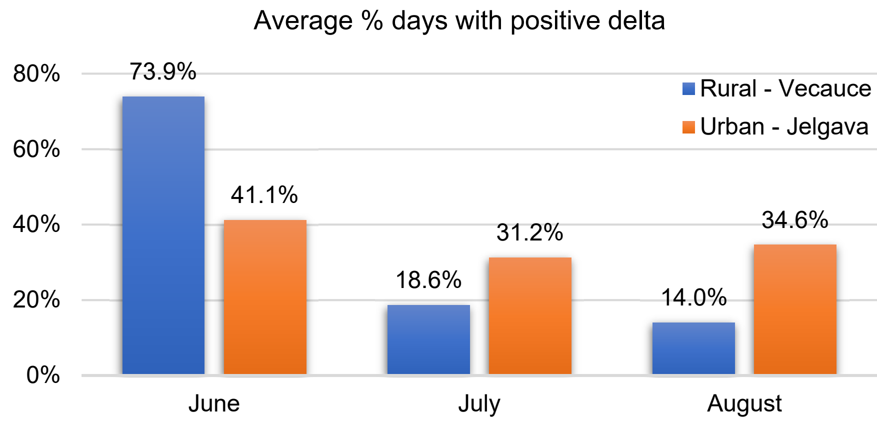

Figure 5. Average numbers of days with a positive weight gain for apiaries.

Table 4 below presents the detailed percentage of days with positive delta from all the days with positive delta.

Table 4. Percentage of days with positive weight gain from all the days with positive delta

	Rural - Vecauce					Urban - Jelgava				
	R_1	R_2	R_3	R_4	R_5	U_1	U_2	U_3	U_4	U_5
June	65.5%	75.0%	100.0%	62.5%	66.7%	64.5%	39.1%	34.7%	41.7%	25.6%
July	13.8%	20.8%	-	25.0%	14.8%	35.5%	28.3%	28.6%	27.8%	35.9%
August	20.7%	4.2%	-	12.5%	18.5%	-	32.6%	36.7%	30.5%	38.5%

The same information can be present in a form of a chart (see Fig. 6) to provide better comparison of the honeybee bee colonies in different locations.

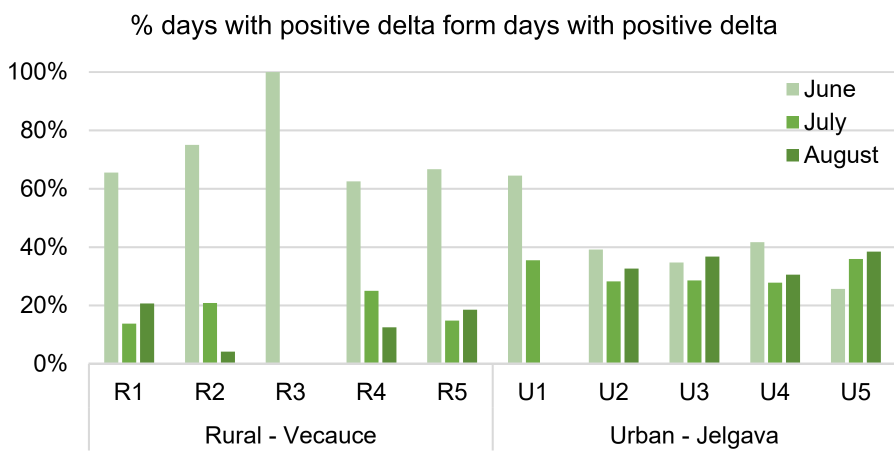

Figure 6. Percentage of days with positive weight gain from days with positive delta.

But the Table 5 below shows the percentage of days with positive delta from all days.

Table 5. Percentage of days with positive delta from all days

	Rural - Vecauce					Urban - Jelgava				
	R_1	R_2	R_3	R_4	R_5	U_1	U_2	U_3	U_4	U_5
June	63.3	60.0	63.3	66.7	60.0	66.7	60.0	56.7	50.0	33.3
July	12.9	16.1	-	25.8	12.9	35.5	41.9	45.2	32.3	45.2
August	19.4	3.2	-	12.9	16.1	-	48.4	58.1	35.5	48.4

By analysing the data, it can be observed that colonies in the urban environment have a positive increase of weight during the whole period, so there are some foraging resources throughout the summer. But the rural apiary is limited to some days of the flowering period, and it can be seen that after intensive and high foraging activity, very small amounts of other foraging sources and plants are available for bees.

Authors should stress out, that current study and bee colony monitoring is limited to one foraging season and one location for each apiary (urban and rural). If bees perform better or worse in one location, it may be because of the particularities of specific location, such as localized pesticide application or intense landscaping with bee-friendly plants, rather than due to urban or rural environments in general.

CONCLUSIONS

Based on the bee colony monitoring and evaluation of the weight gain it can be concluded that for the urban apiary foraging resources are available during the whole summer period, but rural apiary mostly has a decrease in weight in July and August.

Colonies in a rural environment can achieve high foraging performance during several intensive flowering days of the main agricultural crops, like rapeseed and beans.

Remote monitoring of the bee colonies can indicate the start and the end dates of the nectar flow and beekeepers can then decide the necessity to transfer the colonies to other locations.

The monitoring results suggested that colonies in the urban environment also can gain a sufficient amount of resources which can be converted to honey or other bee products.

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