MONITORING AGROMETEOROLOGICAL FACTORS AND BEEHIVE WEIGHT DURING SUNFLOWER (*HELIANTHUS ANNUUS*) FLOWERING

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Abstract. The impact of local agrometeorological factors on beehive changing weight during sunflower (*Helianthus annuus*) flowering was monitored. The study was conducted in 2021 growing season in a hilly flat area with predominant agricultural crops. The location of the experimental apiary is 43º32'4.02"N and 25º45'14.10"E at an altitude of 223 m. The experimental apiary consisted of 122 bee colonies housed in Dadant-Blatt hives. The bees are of the species (*Apis mellifera macedonica*). The total number of fields sown with sunflower was 6. All sunflower fields were located within a radius of the bees' optimal flight area. During the experiment there were observed the outside air temperature (T_{air}), 0ºC and air humidity (H_{air})%, atmospheric pressure (A_p) hPa, soil moisture (S_m), % at 20 cm depth, soil temperature (S_t), ºC at 10 cm depth, solar radiation (S_r) W·m^{-2}, wind speed (W_s), m·s^{-1}, precipitated rainfall (R), l·m^{-2}. Also the air temperature inside (T_{in}) the hive was measured. The nectar flow is determined based on the changes in hive weight (*Y*). The real-time data were available via a web-based application Meteobot®. The results show that there is a significant positive correlation between Y and honey harvesting date D, honey harvesting time per day *T*, T_{air}, S_t, A_p. The other weather indicators as H_{air}, S_m W_s D_p, T_{in} are negatively correlated with Y. The indicator S_r is not correlated with Y. The monitoring of the agrometeorological factors and beehive weight during sunflower flowering will help the beekeepers determine the suitable moment for expanding the capacity of the hive and honey extracting.

Keywords: agrometeorological factors, honey bee, apiary, sunflower.

Introduction

The sunflower is one of the main oil crops in the world. In Bulgaria, the sunflower is in first place among the cultivated oil crops. Sunflower areas for 2021 occupied 24.1% of the arable land, and in 2022 they occupied 28.5% of the arable land [1]. The harvested amount of oilseed sunflower is 3.3% more compared to 2021. The most areas occupied by oilseed crops for 2022 are in north-eastern Bulgaria 22.1% and 22.8% in north-western Bulgaria [1]. Besides, as an oilseed crop, the cultivation of sunflower is of great importance for beekeeping. It is one of the four main pastures for the flat and hilly regions of northern and north-eastern Bulgaria. Sunflower plays a key role in stockpiling bee colonies with honey and pollen for the winter period. The cultivation of sunflower near the bee colonies helps reductions in varroa mite infestation of honey bee colonies [2]. The sunflower (*Helianthus annuus*) pollen reduced a microsporidian pathogen (*Nosema ceranae*) of the European honey bee (*Apis mellifera*) [3]. Bees are one of the main pollinators of sunflowers [4]. The presence of bee colonies next to sunflower fields helps pollinate it effectively and obtain higher seed yields [5].

The climate change in Bulgaria in recent years, poor agricultural practices and the cultivation of sunflower hybrids with a short growing season have led to disruption of the normal development of bee colonies in autumn and high winter mortality among bee colonies. Over the past two years, winter mortality among bee colonies has increased. In 2021, over 81 thousand bee colonies died in Bulgaria, which is 84.0% more compared to 2020 [6]. The climate change in individual regions has an impact on the amount of nectar secreted from sunflower inflorescences and the flight activity of foraging bees [7]. An important factor affecting the normal existence of bee colonies is the quality of the secreted nectar in individual hybrids. According to [8] the attendance of bees in different sunflower hybrids depends on the content of nectar sugar. Some of the listed factors affecting the strength of bee colonies are controllable, but others, such as climate change, are not controllable, which is why their monitoring is necessary. Monitoring of climatic factors during the growing season of plants and collecting a database of the specific microclimatic conditions for a given region is essential for the development of forecasting models. Modelling of honey bee (*Apis mellifera*) foraging activity and local climate conditions is shown in [9].

The transfer of good practices from precision agriculture to precision beekeeping allows us to carry out remote monitoring of some external factors affecting flowering plants and bee colonies, such as air and soil temperature and humidity, wind speed and direction, atmospheric pressure, solar radiation etc. Also, precise technologies allow us to measure some internal indicators, such as temperature, humidity and C_2O inside the hive, vibration and sound disturbances, number of foraging bees leaving and returning to the hive, weight of the hive etc. The application of intelligent sensor systems can provide insight into the state of the colony, its interaction with the environment and the influence of climatic conditions [10-12].

The aim of our study is remote monitoring the influence of local agrometeorological factors on hive weight changes during sunflower (*Helianthus annuus*) flowering.

Materials and methods

The study was conducted in the summer of 2021 in an experimental apiary located in the village of Brestovica with geographical coordinates 43º32’4.02” N and 25º45’14.10” E at an altitude of 223 m, Fig.1. Within a radius of 3 km. around the studied apiary, the predominant main pastures are rapeseed (*Brassica napus*), acacia (*Robinia pseudoacacia*), linden (*Tilia cordata*) and sunflower (*Helianthus annuus*). A large part of the arable land around the apiary is occupied by sunflower with a total area of 244 ha. The sunflower is the last major pasture for the region and is of great importance for stocking bee colonies with food reserves for the winter and obtaining commercial honey. The fields were sown with Syngenta’s Bacardi CLP sunflower hybrid. The experimental apiary in Brestovica consisted of 122 bee colonies housed in Dadant-Blatt hives 12 wooden frames made of softwood with the following dimensions: length of the hive 516 mm, width 516 mm, height 400 mm, wall thickness: 34 mm. For remote monitoring, 12 bee colonies previously equalized in strength, amount of sealed brood, food reserves (honey and pollen) and young queen bees of one year were selected. The bees are of the species (*Apis mellifera macedonica*). The total number of bee colonies within a radius of 3 km from the experimental apiary is 692, which provide some competition to the colonies studied by us [13]. In our research, we have excluded the influence of this factor on the change in hive weight.

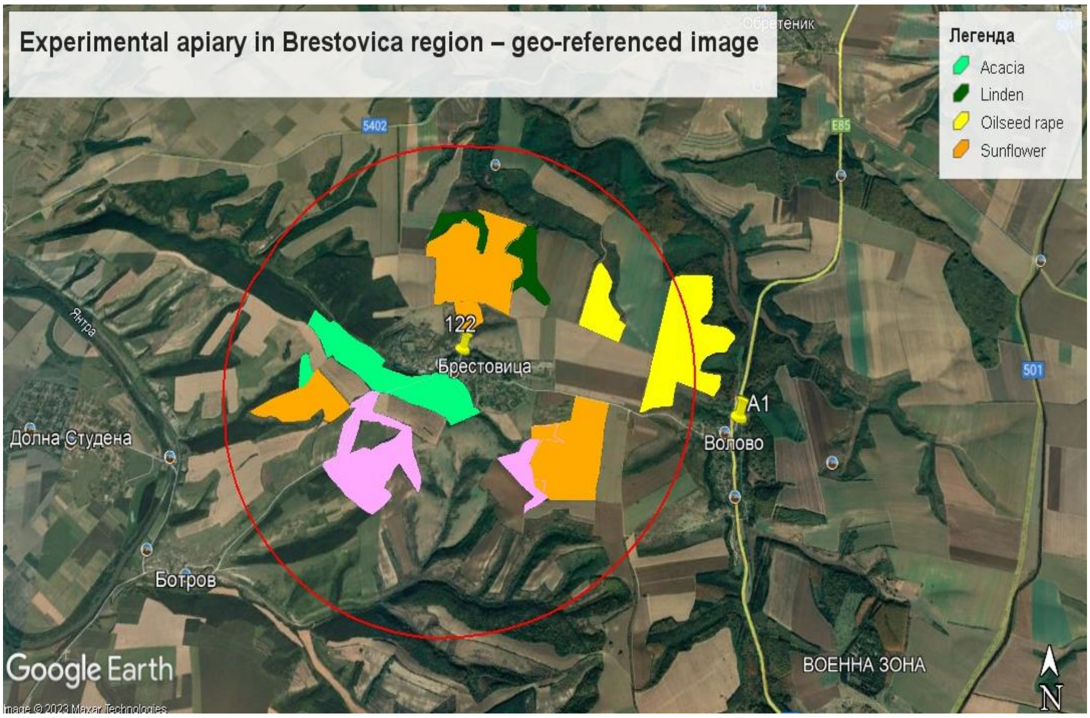


Fig.1. **Experimental apiary in Brestovica region – geo-referenced image**

The remote monitoring of agrometeorological factors was carried out with a precision apiculture system (PAS) including the following elements: 1 – box with electronic circuit board, 2 – rain sensor – Pronamic professional rain gauge, 3 – wind speed sensor – Thies Clima 4.3515.51.000, 4 – solar panel, 5 – air humidity and atmospheric pressure sensor – Sensirion SHT-31, 6 – leaf moisture sensor, 7 – soil temperature sensor and beehive air temperature sensor - Quick-Teck DS18B20, 8- soil moisture sensor- Irrometer Watermark 200SS, rechargeable battery, shown in Fig.2. The Meteobot® electronic block consists of a number of components (microprocessor, GSM/GPRS modem, SIM card holder, antenna, input ports, output ports, etc.) on a printed circuit board. The electronic block receives signals from sensors through the input ports, processes the signals, and sends the data over a mobile data network (GSM/GPRS) to the Meteobot® cloud server. The frequency range is 880 – 915/925 – 960 and 1710 – 1785/1805 – 1880. The data transmission interval is 10 minutes.

The monitoring was conducted in the period from 2 July 2021 and ended by 27 July.2021. For our study, we selected 5 days in a row from 6 July 2021 to 10 July 2021 when the sunflower was in full bloom and when the nectar flow was highest. The average flow of nectar from the twelve observed colonies was 5.32 kg. for July 6; 6.98 kg. for July 7; 5.06 kg for 8. July; 5.02 kg for July 9 and 4.76 kg for July 10.

Fig. 2. **Precision apiculture system sensors**

During the experiment were measured within-day indicator changes as the outside air temperature (T_{air}), ºC and air humidity (H_{air})% , atmospheric pressure (A_p) hPa, soil moisture (S_m) at 20 cm depth, %, soil temperature (S_t) at 10 cm depth, ºC, solar radiation (S_r) $W \cdot m^{-2}$, wind speed (W_s), $m \cdot s^{-1}$, precipitated rainfall (R), $l \cdot m^{-2}$ and the dew point D_p. During the study precipitation was not recorded and in the statistical processing of the obtained data precipitation was not taken into account. Also the air temperature inside (T_{in}), ºC the hive was measured. T_{in} was almost the same 35.9 ºC and 36 ºC and was not taken into account. The nectar flow is determined based on the changes in the hive weight (Y), kg. The real-time data were available via a web-based application Meteobot® [3]. The recording of the change in the weight of the hive was carried out with an electronic beekeeping scales of TEHTRON-VAGA with a range of up to 200 kg and measurement precision up to the second digit after the decimal point. For the purpose of the experiment, the 12 experimental hives were equipped with scales of this type. The frequency (T) for reading indicators of external and internal factors in the hive and change in the weight of the hive is every 30 minutes from 7:30 a.m. to 20:00 p.m.

Relationship between weather conditions and changing the weight of the hive was analysed by Spearman coefficient and software STATISTICA 10 (StataCorp LP®, USA) was used.

Results and discussion

Based on phenological observations of flowering plants in the region of Brestovica, it was established that sunflower flowering began on 2 July 2021 and ended by 27 July.2021, Fig. 3. The duration of the flowering period is 25 days.

The real-time data were available via a web-based application Meteobot®, Fig.4. The measured mean values of T_{air} for the flowering period was 24. 9 ºC, H_{air} was 67.04% and S_r was 252.27 $W \cdot m^{-2}$. W_s, A_p, S_m. The amount of precipitation is 0.25 $l\ m^{-2}$. The difference in the measured values of T_{air}, H_{air}, S_r and W_s determines the specific microclimate for the study area.

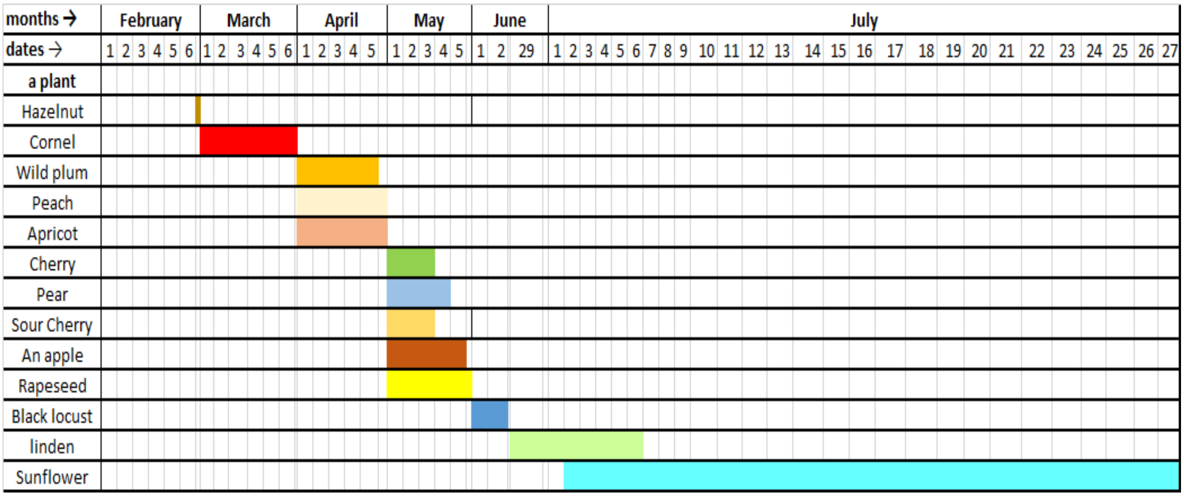
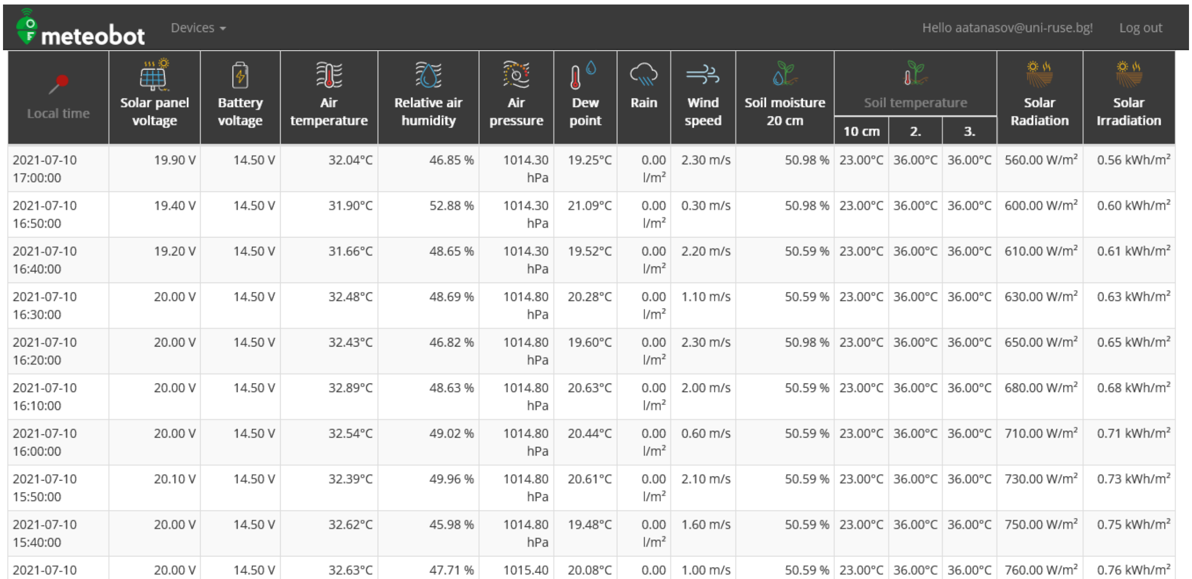


Fig. 3. **Phenological observations of flowering plants in the region of Brestovica**



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Local time	Solar panel voltage	Battery voltage	Air temperature	Relative air humidity	Air pressure	Dew point	Rain	Wind speed	Soil moisture 20 cm	Soil temperature 10 cm	Soil temperature 2.	Soil temperature 3.	Solar Radiation	Solar Irradiation
2021-07-10 17:00:00	19.90 V	14.50 V	32.04°C	46.85 %	1014.30 hPa	19.25°C	0.00 l/m²	2.30 m/s	50.98 %	23.00°C	36.00°C	36.00°C	560.00 W/m²	0.56 kWh/m²
2021-07-10 16:50:00	19.40 V	14.50 V	31.90°C	52.88 %	1014.30 hPa	21.09°C	0.00 l/m²	0.30 m/s	50.98 %	23.00°C	36.00°C	36.00°C	600.00 W/m²	0.60 kWh/m²
2021-07-10 16:40:00	19.20 V	14.50 V	31.66°C	48.65 %	1014.30 hPa	19.52°C	0.00 l/m²	2.20 m/s	50.59 %	23.00°C	36.00°C	36.00°C	610.00 W/m²	0.61 kWh/m²
2021-07-10 16:30:00	20.00 V	14.50 V	32.48°C	48.69 %	1014.80 hPa	20.28°C	0.00 l/m²	1.10 m/s	50.59 %	23.00°C	36.00°C	36.00°C	630.00 W/m²	0.63 kWh/m²
2021-07-10 16:20:00	20.00 V	14.50 V	32.43°C	46.82 %	1014.80 hPa	19.60°C	0.00 l/m²	2.30 m/s	50.98 %	23.00°C	36.00°C	36.00°C	650.00 W/m²	0.65 kWh/m²
2021-07-10 16:10:00	20.00 V	14.50 V	32.89°C	48.63 %	1014.80 hPa	20.63°C	0.00 l/m²	2.00 m/s	50.59 %	23.00°C	36.00°C	36.00°C	680.00 W/m²	0.68 kWh/m²
2021-07-10 16:00:00	20.00 V	14.50 V	32.54°C	49.02 %	1014.80 hPa	20.44°C	0.00 l/m²	0.60 m/s	50.59 %	23.00°C	36.00°C	36.00°C	710.00 W/m²	0.71 kWh/m²
2021-07-10 15:50:00	20.10 V	14.50 V	32.39°C	49.96 %	1014.80 hPa	20.61°C	0.00 l/m²	2.10 m/s	50.59 %	23.00°C	36.00°C	36.00°C	730.00 W/m²	0.73 kWh/m²
2021-07-10 15:40:00	20.00 V	14.50 V	32.62°C	45.98 %	1014.80 hPa	19.48°C	0.00 l/m²	1.60 m/s	50.59 %	23.00°C	36.00°C	36.00°C	750.00 W/m²	0.75 kWh/m²
2021-07-10	20.00 V	14.50 V	32.63°C	47.71 %	1015.40	20.08°C	0.00	1.00 m/s	50.59 %	23.00°C	36.00°C	36.00°C	760.00 W/m²	0.76 kWh/m²

Fig. 4. **Meteobot® interface real-time data visualisation**

For the monitoring period, we studied the dynamics of the change in the weight of the hive during an interval of 30 min due to the flow of nectar into the hive. Fig.5 shows the time dynamics of the change in the weight of the hive for the measurement period. It was found that in the initial hours of measurement between 7:30 and 8:30 a.m., a reduction in the hive weight was observed on average over the entire observation period by 0.353 kg. The decrease in the weight of the hive is due to evaporation of water from the nectar brought in the previous day and the departure of a large number of foraging bees from the hive to the sunflower field. A similar reduction in the hive weight was reported on 6 July at 14:00 p.m. and at 16:00 p.m. on 8-9 July and between 15:30 p.m. and 16:30 p.m. on 10 July. From Fig. 4 it can be seen that for the period of observation the highest values of weight increase of the hive with an average of 0.638 kg were recorded between 9:30 a.m. and 11:30 a.m. due to the return of the forager bees to the hive.

The change in the weight of the hive during the individual days of monitoring is summarized in Fig. 6. On the first day of observation, the amount of nectar received in the hive with the duration of collection 13.30 h. was 5.32 kg. On the second day we have an increase in inflow of 1.66 kg compared to the first day. During the remaining three days, a smooth decrease of 0.26 kg., 0.30 kg. and 0.56 kg. was observed compared to the first day, which confirms the statement about the influence of the change in the feeding environment on the flow of nectar in the hive.

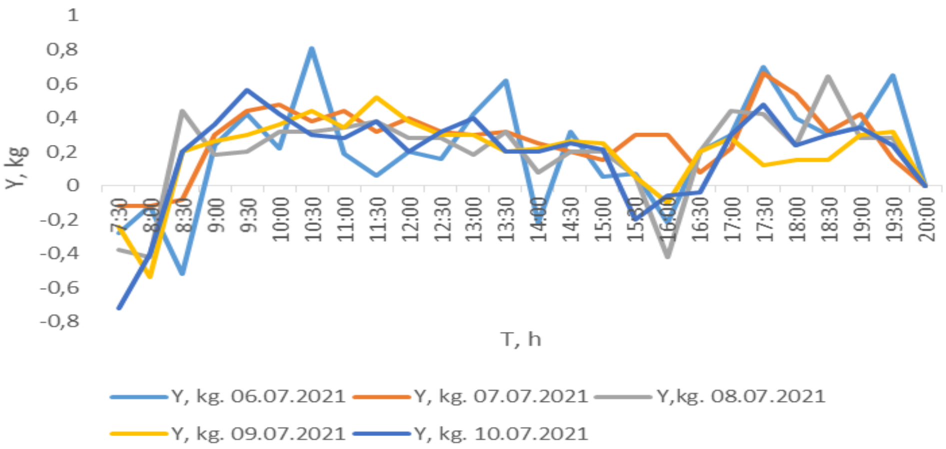

Fig. 5. **Change in the weight of the hive for the measurement period in Brestovica**

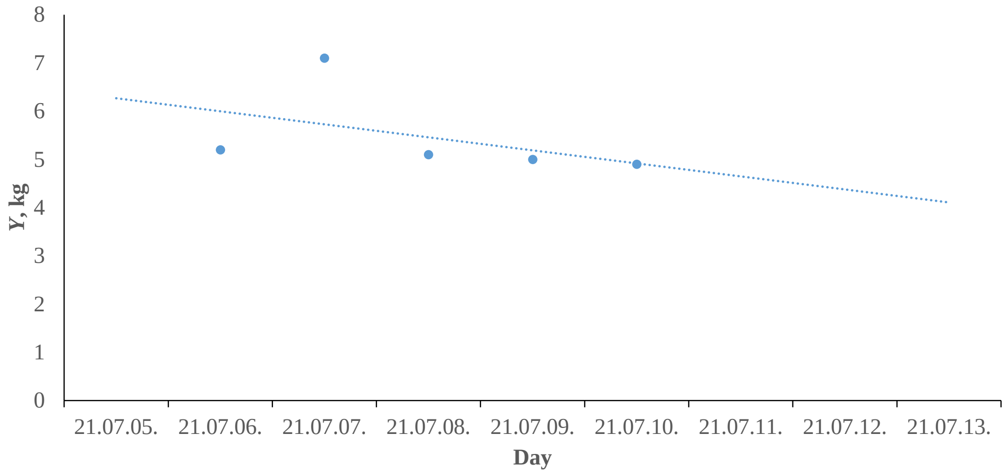

Fig. 6. **Average daily weight change of the hive for the measurement period**

According to [11] continuous monitoring of the honey bee colony weight allows to identify daily patterns of their activity during sunny summer days. In our research for the days from 8 to 10 July, a smooth cyclicity of the variation of the hive weight was found, as the main indicator of the distribution of the activities of the bees during foraging, including nectar processing by reducing the water content at night; taking off and foraging; returning to the hive with collected nectar, Fig. 7.

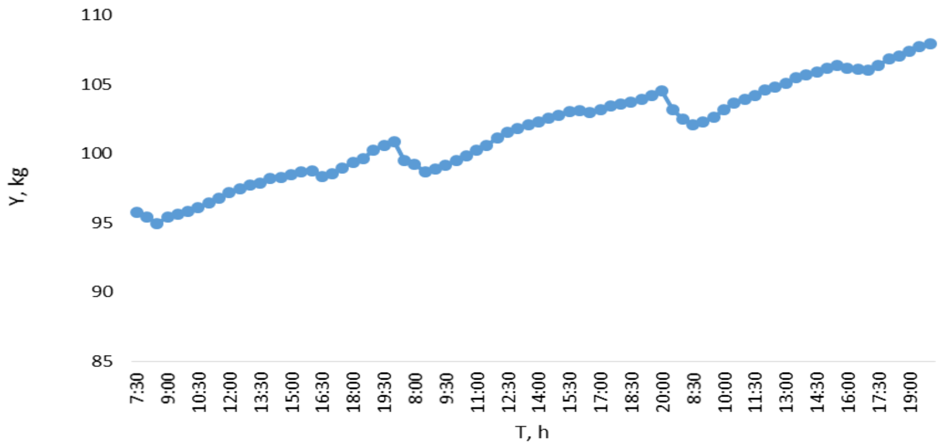

Fig. 7. **Daily routine of the honey bee colony**

The trend line shows that with each subsequent day we have a periodic increase in the weight of the hive, although at night the weight decreases by an average of 1.330 kg per evening. The amount of reduction in the weight of the hive during the night is an indicator of the amount of water evaporated and the amount of honey consumed to maintain the vital functions in the colony.

The relationship between weather conditions and changing the weight of the hive was analysed by Spearman's rank correlation coefficients, Table 1. For statistical processing of the data, averaged values of the change in the weight of the 12 hives were used.

Table 1

Spearman's rank correlation coefficients between weather conditions and *Y*, marked correlations are at $p < 0.05$

	D	T	H_{air}	T_{air}	S_m	S_t	S_r	W_s	A_p	D_p
D	1.000									
T	0.000	1.000								
H_{air}	-0.475	-0.374	1.000							
T_{air}	0.160	**0.331**	-0.776	1.000						
S_m	-0.950	0.039	0.411	-0.144	1.000					
S_t	**0.272**	**0.731**	-0.257	**0.327**	-0.213	1.000				
S_r	0.118	-0.325	-0.390	**0.594**	-0.158	-0.285	1.000			
W_s	-0.227	-0.054	-0.203	**0.318**	0.195	-0.089	**0.362**	1.000		
A_p	**0.532**	-0.169	0.033	0.053	-0.585	0.243	0.147	-0.034	1.000	
D_p	-0.335	0.124	-0.011	**0.572**	0.290	0.195	**0.433**	**0.282**	**0.231**	1.000
Y	**0.960**	**0.268**	-0.542	**0.238**	-0.907	**0.470**	0.020	-0.240	**0.477**	-0.291

The results summarized in Table 1 show that there is a significant positive correlation between Y and the honey harvesting date D (r = 0.960), honey harvesting time per day T (r = 0.268), T_{air} (r = 0.238), S_t (r = 0. 470), A_p (r = 0.477). The other weather indicators as H_{air}, S_m W_s D_p are negatively correlated with Y. The indicator S_r is not correlated with Y.

Conclusions

1. The change of local agrometeorological factors during flowering of the sunflower (*Helianthus annuus*) affects the change in the nutrient environment and the nectar flow in the hive.
2. The relationship between changes in the hive weight Y and honey harvesting date D (r = 0.960), honey harvesting time per day T (r = 0.268), outside air temperature T_{air} (r = 0.238), solar radiation S_t (r = 0.470), atmospheric pressure A_p (r = 0.477) at $p < 0.05$ shows that we have a significant positive correlation.The other weather indicators as the air humidity H_{air}, soil moisture S_m wind speed W_s dew point D_p are negatively correlated with Y. The indicator S_r is not correlated with Y.
3. Remote monitoring of the agrometeorological factors and changes in the hive weight allows accurate assessment of honey flows in different sunflower hybrids and a management decision by beekeepers.

Acknowledgements

This research is supported by the Bulgarian National Science Fund under Project KP-06-PN 46-7 "Design and research of fundamental technologies and methods for precision apiculture".

Author contributions

Conceptualization, A.Z.A.; methodology, A.Z.A. and I.S.H.; software, A.Z.A.; validation, A.Z.A. and V.Y.D.; formal analysis, A.Z.A and I.S.H..; investigation, A.Z.A., I.S.H. and V.Y.D.; data curation, A.Z A., V.Y.D.; writing – original draft preparation, A.Z.A.; writing – review and editing, I.S.H. and V.Y.D.; visualization, A.Z.A., and I.S.H.; project administration, A.Z.A.; funding acquisition, A.Z.A. All authors have read and agreed to the published version of the manuscript.

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