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Monitoring honeybee (*Apis mellifera*) flight activity and within-day hive weight changes during rapeseed (*Brassica napus*) flowering

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Abstract— Honeybee (*Apis mellifera*) flight activity and beehive changing weight during rapeseed (Brassica napus) flowering was evaluated. The research was carried out during the 2021 agricultural period in the northeastern region of Bulgaria, specifically in Yuper village. The experimental site is situated at 43°54'28.59" N, 26°23'49.02"E coordinates, with an elevation of 107 meters. Within the experiment, there were 130 bee colonies kept in Dadant-Blatt hives. The bees belong to the species known as (*Apis mellifera macedonica*). Throughout the research duration, the study focuses on tracking the quantity of bees leaving the hive (N_{bee}) and the changes in hive weight (Y) caused by the secretion of nectar during different time intervals throughout the day. The monitoring included external factors such as the temperature of the outside air (T_{air}), ^{0}C, the humidity of the air (H_{air}) %,, and the surface temperature (T_{sur}) ^{0}C, of the rapeseed inflorescences. The findings indicate a noteworthy and favorable relationship between N_{bee} and Y. The stronger correlation between N_{bee}, Y and T_{sur} was found. The other weather indicators as T_{air} and H_{air} are not correlated with N_{bee} and Y. The monitoring of the honeybee flight activity and beehive weight during rapeseed flowering will help the beekeepers to determine the suitable moment to expand the bee colonies in order to achieve optimal productivity.

Keywords— honeybee, flight activity, hive weight, rapeseed

I. Introduction

The winter rapeseed (Brassica napus) plays a significant role as a bee foraging resource in the flat and hilly areas of central and north-eastern Bulgaria. It is the first important main pasture on which the development of bee colonies in the spring and their productivity throughout the entire beekeeping season largely depends. The correct use of the bee pasture during the flowering of canola depends on meteorological factors, the strength of bee colonies, and the overpopulation of bee colonies in a local geographical region and the technology of beekeeping.

Meteorological factors in each local geographical region largely determine honey production. Unfortunately, the management of meteorological factors is not within the capabilities of the beekeeper, but their observation is important for making correct decisions related to the expansion of the bee nest, the placement of additional enclosures, the relocation of the bee colonies and etc.

Many of the technological operations for the observation of bee colonies are manually carried out by the beekeeper, at the opening of each bee colony. From the experience gained in the use of Information and Communication Technology (ICT) in other sectors of agriculture, it is possible to transfer best practices for beekeeping digitalisation. In apiculture, ICT can be utilized to assist beekeepers by implementing automated or semi-automated solutions for managing bee colonies, recording apiary data, and facilitating various operations. Intelligent sensor systems have the potential to offer valuable information about the condition of the colony, its interaction with the environment, and the impact of climatic conditions [1], [2], [9], [10].

Ensuring an adequate supply of nectar and pollen to the hive is crucial for replenishing the colony's food reserves and has an impact on the hive's weight. Previous studies [2], [3], [4], [6], [12] have investigated the correlation between changes in hive weight and weather conditions.

The flight activity of honey bee depends on nectar extraction from flowering plants and weather conditions. According to [5] the significant rise in the surrounding temperature adversely affects both the blooming of rapeseed and the foraging behaviour of honey bees.

Bees are important pollinators in nature, on which the pollination and yield of a number of agricultural crops depends. The influence of bees on seed yield in oilseed rape was studied by [8], [11].

The diversity of the microclimate in the local geographical areas in Bulgaria, the biodiversity of the flowering vegetation, the strength of the bee colonies, the locations of the apiaries and the competition between them necessitate the conduct of experimental studies for individual areas. Automatic transfer of data from one area to another would lead to incorrect decision-making.

Our study aims to observe how local agrometeorological factors affect the flight activity of bees and the changes in hive weight within a day, specifically during the flowering period of rapeseed (*Brassica napus*).

II. Material and Methods

The research took place during the 2021 growing season in the northeastern region of Bulgaria, specifically in the village of Yuper. The experimental area is situated at a geographical location of 43°54'28.59" N, 26°23'49.02"E, with an altitude of 107 meters. Oilseed rape (Brassica napus) serves as a significant nectar source for honeybees and is the primary early-season forage in the region. The experimental apiary, depicted in "Fig.1" comprised 130 bee colonies accommodated in Dadant-Blatt hives. These hives were constructed for 12 wooden frames. The hives are featuring dimensions of 516 mm in length, 516 mm in width, and 400 mm in height, with a wall thickness of 34 mm. For remote monitoring, 6 bee colonies previously equalized in strength,

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amount of sealed brood, food reserves (honey and pollen) and young queen bees of one year were selected.

Fig. 1. Experimental apiary in village Yuper

The experimental apiary "Fig. 2" was located 2360 meters from the firs oilseed rape field and 2086 meters to the rape field. The total area of canola fields in the flight range of the bees was 77.99 h. The total number of bee colonies in Yuper region are 568, which provide some competition to the colonies. In our research, we have excluded the influence of this factor on the change in hive weight.

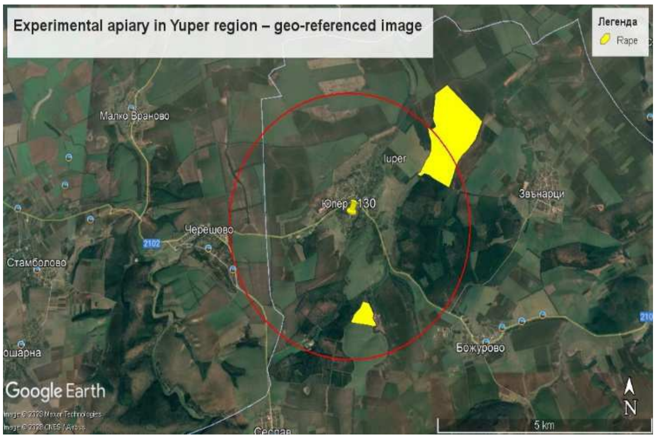

Fig. 2. Geo-referenced image of experimental apiary in village Yuper

The honeybees in this study belong to the species (*Apis mellifera macedonica*). There are various factors that can influence the foraging activity of honeybees, which can be categorized into two main groups: in-colony factors and out-colony factors [7]. In this research, we considered the impact of certain external factors, which were measured using a precision apiculture system (PAS), [3]. Throughout the study period, we monitored the number of bees leaving the hive (N_{bee}) and the changes in hive weight (Y), kg^{-1} due to nectar flow at different times of the day. External factors such as outside air temperature (T_{air}), ^0C, air humidity (H_{air}), % and surface temperature (T_{sur}), ^0C on the rapeseed inflorescences were also observed. T_{air} and $H_{ai}r$ were measured using a combined temperature/humidity sensor called DHT22, which was located on the PAS. Real-time data were accessible through the web-based application Meteobot®.

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 surface temperature of oilseed rape inflorescences was measured with a CAT S61 c FLIR ONE PRO unit thermal camera. A bee scale from TEHTRON-VAGA was used to measure the weight of the hive (Y), kg/hive with a range of up to 200 kg and measurement precision up to the second digit after the decimal point. The counting of the bees leaving the hive was done organoleptically. Data recording took place every 30 minutes between 9:30 a.m. and 19:00 p.m. The start and end times of the experiment were determined based on the presence of nectar flow into the hive. No increase in Y (hive weight change) was observed in the hours prior to 9:30 a.m. and after 19:00 p.m.

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

III. Results and Discussions

For our study, we specifically selected days without rainfall and with an average wind speed of 1.2 m/s, when meteorological conditions allowed normal bee flight and oilseed rape was in full bloom. Flowering duration of oilseed rape in the Yuper region was 23 days, with the last 6 days overlapped with the next main pasture of black locust (*Robinia pseudoacacia*). According to "Fig. 3" the greatest hive weight changes were recorded at 12:30 p.m., 15:00 p.m., 16:30 p.m., and 19:00 p.m. during these three experimental days in the Yuper region. Conversely, the lowest values were observed in the morning, specifically between 9:30 a.m., 12:00 p.m., 14:30 p.m., 15:30 p.m. and 20:00 p.m. We observed a cyclical pattern of increasing and decreasing nectar flow within 30 minute intervals.

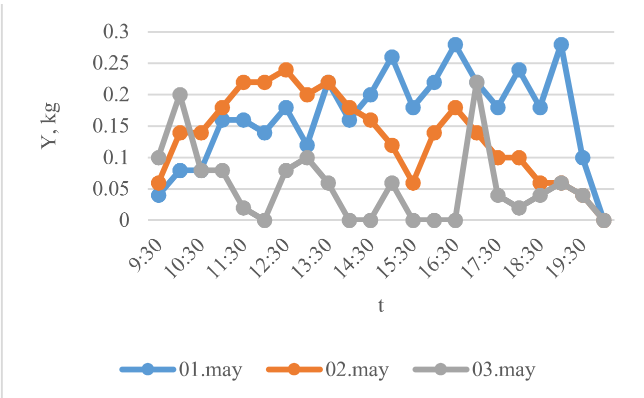

Fig. 3. Measured hive weight for the days of the experiment

For the statistical processing of the data, averaged values of the change in weight of the 6 hives were used. Relationship between weather conditions and traffic honey bee and changing the weight of the hive was analyzed by Spearman's rank correlation coefficients "Tab. I".

TABLE I. SPEARMAN'S RANK CORRELATION COEFFICIENTS BETWEEN WEATHER CONDITIONS AND N_{BEE} AND Y.

	t	**T_{air}**	**H_{air}**	**T_{sur}**	**N_{bee}**	**Y**
t	1,000000	-0,042815	-0,509241	-0,503030	-0,838910	-0,713931
T_{air}	-0,042815	1,000000	-0,749230	**0,642229**	0,193255	0,304354
H_{air}	-0,509241	-0,749230	1,000000	-0,165657	0,332322	0,105920
T_{sur}	-0,503030	**0,642229**	-0,165657	1,000000	**0,717329**	**0,670849**
N_{bee}	-0,838910	0,193255	0,332322	**0,717329**	1,000000	**0,817964**
Y	-0,713931	0,304354	0,105920	**0,670849**	**0,817964**	1,000000

Marked correlations are significant at $p < ,05000$

The results summarized in Table I shows that there is a significant positive correlation between N_{bee} and Y (r = 0, 817964). A strong positive correlation between T_{sur} and N_{bee} (r = 0, 717329) was found. The correlation is positive and between T_{sur} and Y (r = 0, 817964). A positive correlation was found between T_{air} and T_{sur} (r = 0,652229).

The correlation between the departure intensity of bees from the hive and the corresponding changes in hive weight is shown in "Fig. 4".

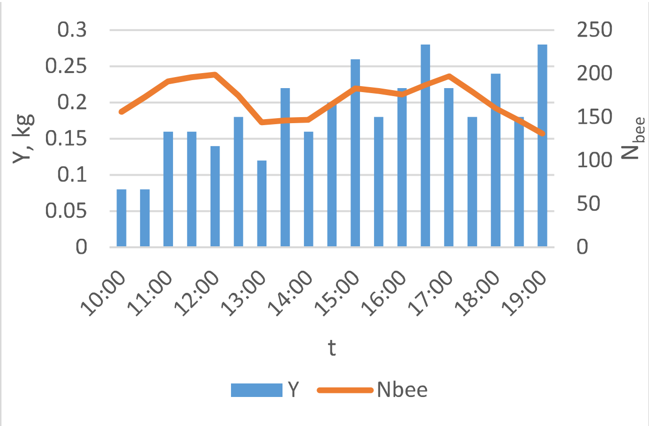

Fig. 4. Change in the number of bees leaving the hive N_{bee} and weight of the hive Y, kg.

Observed that between 10:00 a.m. and 12:00 p.m. there was an increase in the number of bees leaving the hive by an average of 11 bees and the increase in hive weight was insignificant with between 0.04 and 0.08 kg per hive every 30 minutes. From 12:00 p.m. to 13:00 p.m., the number of bees leaving the hive decreased by 27 every 30 minutes. Between 13:00 p.m. and 17:00 p.m. there is a gradual increase in the number of bees leaving the hive, as between 15:00 p.m. and 17:00 p.m. there is a steady increase in the number of bees leaving with an average of 11 bees every 30 minutes. After 17:00 p.m., the number of bees leaving decreased by 17 every 30 minutes. At 13:30 p.m. an increase in the flow of nectar into the hive by 0.22 kg was observed. The highest levels of hive weight gain of 0.26 to 0.28 kg per hive were recorded at 15:00 p.m. and 16:30 p.m. The increase in the weight of the hive at 19:00 p.m. is due to the intensive return of the forager bees to the hive.

The relationship between T_{sur} and N_{bee} is shown in "Fig.5".

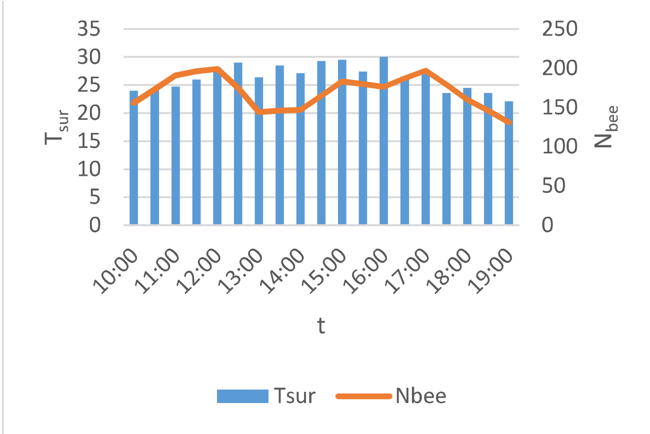

Fig. 5. Change in the number of bees leaving the hive N_{bee} and surface temperature T_{sur} ^{0}C on the rapeseed inflorescences.

The results obtained show that in the hours between 10:00 a.m. and 11:00 a.m. an increase in T_{sur} of 4 ^{0} C was observed, with N_{bee} increasing by 43 numbers of bees at 11:00 a.m. compared to 10:00 a.m. Between 12:00 p.m. and 14:00 p.m. we have a T_{sur} decrease of 1 ^{0} C where N_{bee} decreases by 52 numbers of bees at 14:00 p.m. relative to 12:00 p.m. The T_{sur} increase of 2.4 ^{0} C at 15:00 p.m. relative to T_{sur} at 14:00 p.m. results in an increase of N_{bee} by 36 numbers of bees. At 16:00 p.m. T_{sur} is 0.5 ^{0} C higher than T_{sur} at 15:00 p.m. whereby N_{bee} remains the same. At 19:00 p.m. observed a decrease in T_{sur} of 5.4 ^{0} C relative to T_{sur} at 17:00 p.m., while at the same time N_{bee} decreased by 65 bees at 19:00 p.m. A change in T_{sur} leads to a change in Y, and N_{bee}, which is confirmed by the strong correlation between T_{sur} and Y (r = 0.817964) and T_{sur} and N_{bee} (r = 0.717329).

The relationship between T_{sur} and Y is shown in "Fig.6".

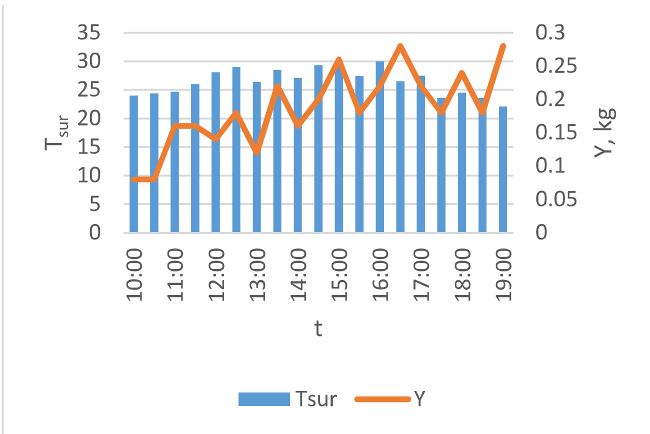

Fig. 6. Change in the surface temperature Tsur ^{0}C on the rapeseed inflorescences and weight of the hive Y, kg.

The analysis of the obtained results shown in "Fig. 6". confirmed that as T_{sur} increases, Y increases too. We observe that Y increases at 12:30 p.m., 13:30 p.m., 15:00 p.m., 16:30 p.m. and 18:00 p.m. The decrease in Y was reported at 13:00 p.m., 14:00 p.m., 15:30 p.m., 17:30 p.m., and 18:30 p.m. The correlation is very strong T_{sur} and Y (r = 0.817964)

CONCLUDIONS

The conducted an investigation into the impact of local agrometeorological factors on the flight activity of bees and the weight of beehives during the flowering of rapeseed (*Brassica napus*). The surface temperature of the rapeseed inflorescences (T_{sur}) significantly influences the number of bees leaving the hive (N_{bee}) and the change in hive weight (Y) at a significance level of $P < 0.05$. A change in T_{sur} leads to a change in Y, and N_{bee}, which is confirmed by the strong correlation between T_{sur} and Y (r = 0.817964) and T_{sur} and N_{bee} (r = 0.717329). The other weather indicators as outside air temperature T_{air} and air humidity H_{air} are not correlated with N_{bee} and Y.

The monitoring of the honeybee flight activity and beehive weight during rapeseed flowering will help the beekeepers to determine the suitable moment to expand the bee colonies in order to achieve optimal productivity.

Our next step of research will be to install automatic devices to count bees leaving and entering the hive, accounting for differences in bee loss from pesticide poisoning, swarming, and adverse environmental factors.

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