INFLUENCE OF CLIMATE CHANGES IN ATMOSPHERIC AIR TEMPERATURE ON THE VITAL ACTIVITY OF BEES

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Abstract

The purpose of this work was to reveal the impact of climatic changes in atmospheric air temperature on the vital activity of bee colonies. To elucidate this impact, Pearson's linear correlation coefficients were calculated between the average monthly temperature of the atmospheric air and the average annual value of each of the 6 main morpho-productive characters of the bee families, such as: queen prolificacy, winter resistance, colony strength and disease resistance, brood viability and honey production. The scientific research was carried out on the families of Apis mellifera bees from the Carpathian race at the experimental apiary of the Institute of Zoology of the Academy of Sciences of Moldova. The average monthly and annual data of the atmospheric air temperature for the last 11 years (2010-2020) from the nearest hydrometeorological station, located at a distance of 27 km from the apiary, were used for the research. During this period, for each individual month, Pearson's linear correlation coefficients were calculated between the average monthly temperature of the atmospheric air and the average value per hive of each of the 6 main morpho-productive characters of bee families, such as: prolificacy of queens, winter hardiness, colony strength and disease resistance, brood viability and honey production. The results of the research demonstrated that the winter resistance of the bee colonies is positively influenced by the atmospheric air temperature from October of last year and from January of the current year (r_{xy} = 0.768 and 0.469). At the same time, the high temperatures of the atmospheric air in the months of July, August and September have a negative influence on the winter resistance of bee families (r_{xy} = -0.479; -0.699 and -0.494). The prolificacy of queens is positively influenced only by January temperatures (r_{xy} = 0.464). High atmospheric air temperatures in February, April and June have a negative impact on the prolificacy of queens (r_{xy} = -0.594; -0.795; -0.691). High temperatures in the second half of the year, especially in the months of July and September, negatively influence the prolificacy of queens the following year (r_{xy} = -0.531; -0.711). The strength of bee families is negatively influenced by the atmospheric air temperatures in April and June (r_{xy} = -0.603; -0.691). The high temperatures in September have a negative impact (r_{xy} = -0.606), and those in October have a positive impact (r_{xy} =0.517) on the strength of the colony the following year. Air temperatures in January and February have a positive influence (r_{xy} = 0.495; 0.511), and those in May have a negative influence (r_{xy} = -0.548) on the viability of the bee brood. Overall, the average annual air temperature has a positive influence on brood viability (r_{xy} = 0.833). Honey production is positively influenced by the atmospheric air temperature in January (r_{xy} = 0.488) and negatively – by the atmospheric air temperature in June (r_{xy} = -0.497). At the same time, the atmospheric air temperatures in July and September have a negative impact (r_{xy} = -0.548; -0.684), and those in October – a positive impact (r_{xy} = 0.513) on the honey production of the bee families in the following year.

Key words: *climate changes, air temperature, vital activity, bees*

INTRODUCTION

In the last decades of the 20th century and the beginning of the 21st century, human society exerts an increasing influence on the climate, in particular, on the Earth's temperature, through the burning of fossil fuels, the cutting of forests and the intensive breeding of animals. These activities generate emissions of enormous amounts of greenhouse gases, which add to those already naturally present in the atmosphere, thus contributing to the greenhouse effect and global warming.

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According to a report by the European Commission (Causes of climate change, 2018), currently the average global temperature on Earth is 0.85°C higher than at the end of the 19th century. Each of the past three decades has been warmer than any previous decade.

In another European source (Consequences of climate change, 2018) it is mentioned that climate change on Earth already has a negative impact on human health. The number of deaths caused by excessive heat has increased in some geographic regions, and we are already seeing a change in the distribution of some water- or vector-borne diseases. The most affected economic sectors of society are: agriculture, forestry, energy and tourism. Global climate change is occurring so rapidly that the survival of many species of plants and animals is threatened. Many terrestrial, freshwater and marine animal species have already migrated. Some plant and animal species are at risk of extinction if global average temperatures continue to rise unchecked, contrary to the Paris Agreement – United Nations Framework Convention on Climate Change (2016) and Council Decision (EU) 2016/1841 (2016).

A report by Greenpeace Research Laboratories (Declinul albinelor, 2013) states that „climate changes such as rising temperatures, changing precipitation patterns and extreme or more irregular weather events are having a negative impact on pollinator populations. Some of these changes may affect them individually, ultimately affecting their communities, which is reflected in the increased rate of extinction of pollinator species." For example, it is documented that honey bees in Poland react to climate change by performing the cleaning flight (the time of "awakening" after wintering) earlier than normal, in line with the phenomenon commonly known as "changing the period of the seasons". The bee clearing flight occurred one month earlier compared to the 25-year average, which was attributed to temperature increases (Sparks et al., 2010).

According to an international source of Climate Change (Earth Org Climate Change, 2022), in addition to excessive temperatures there are several challenges that threaten the existence of the bee, most of which are the result of human activity. Colony Collapse Disorder (CCD) is a phenomenon that was first identified in 2006 and causes the steady and annual decline of bee colonies worldwide. These losses are caused by the factors of agricultural intensification, pesticide use, rising regional temperatures and the emergence of invasive species. Rising regional temperatures are having a negative impact on bee populations, causing widespread dispersal of their habitats. In Australia, the native bee has undergone a gradual shift to coastal and mountainous regions, moving closer to urban centers over time. Similar conditions are found in Europe and North America, where high temperatures and low rainfall have contributed to the decrease in bee population of arid regions. In both cases, proximity to cities or human neighborhoods would cause dangerous stressors for bee colonies, such as smog and pollution.

In research published in the journal Proceedings of the Royal Society B (2022), the authors reported that although environmental conditions varied from year to year, the subalpine region from which they sampled bees was particularly vulnerable to climate change, with overall warming spring temperatures and earlier snowmelt. They found that populations of larger-bodied and cavity-nesting bees in which they build honeycombs declined in abundance as temperatures rose, while populations of smaller, ground-nesting bees increased. This research suggests that climate-induced changes in temperature, snowpack, and summer precipitation can numerically reshape bee communities.

A team of American researchers (State, 2021) carried out, over a period of 14 years, a study analyzing a data set from the United States Geological Survey, regarding the presence of wild bees in more than 1000 locations in Maryland, Delaware and Washington, specifically examining how different bee species and communities respond to agricultural land intensification and climate change drivers. As a result, the authors found that wild bees are more affected by climate change than by disturbances to their habitats. Research suggests that addressing land use issues will not be enough to protect these important pollinators.

Climate change can lead to the modification of flowering patterns, to the displacement of the flowering period of some honey plants that represent a major source of food for bees, or to the modification of the period of the seasons, in which case the flowering period no longer corresponds to the time when the bees „wake up" spring (Kremen et al., 2007).

By changing the timing and patterns of plant flowering, climate change also affects the interaction between pollinators and their food source. Thus, research by some authors (Memmott et al., 2007) demonstrates that 17-50% of pollinator species suffer from lack of food in the case of realistic climate change scenarios that cause changes in plant flowering patterns. The authors anticipate that the result of these effects may lead to the potential extinction of both pollinators and plants, disrupting the essential interaction between them.

At the same time, in the bibliographic sources analyzed above, in addition to the general conclusions made by the authors, there is a lack of information regarding the concrete influence of climate changes on the evolution of the morpho-productive characters of bee families over a longer period of years.

According to the data of some of our previous researches, it was demonstrated that excessively high temperatures in the spring-summer of a dry year caused a drastic decrease in the values of the main morpho-productive indices of bee families by 20-46% (Cebotari et al., 2013).

In our other research, carried out over a period of 7 years, it was found that climatic changes in air temperature in different months of the year have different impacts on the vital activity of bee families depending on the time of year and air temperature values (Cebotari et al., 2019).

In this context, the aim of the present paper was to reveal the impact of climatic changes of the atmospheric air temperature on the vital activity of *Apis mellifera* bee colonies by determining the correlative links between the parameters of the monthly atmospheric air temperature in different seasons of the year and the evolution of the value of the morpho-productive characters of the bee families bees over a long period of 11 years.

MATERIAL AND METHOD

The scientific researches were carried out on the families of *Apis mellifera* bees from the *Carpathian* race at the experimental apiary of the Institute of Zoology of the Academy of Sciences of Moldova, located in the area of the Center of Moldavian Forest, Forest District Ghidighici, Canton no. 8, Forest sector no. 21. There were a total of 50 families of bees in the apiary. In each family of bees in the apiary, every year, over a period of 11 years (2010-2020), the main morpho-productive characters of reproduction and development (prolificity of the queen, strength of the family), resistance to wintering and against diseases, the viability of the brood, as well as the productivity of the amount of honey accumulated in the nest, according to the methods developed by us (Cebotari et al., 2010) for the Zootechnical Norm regarding the rating of bee families, the raising and certification of bee brood material, approved by the Decision of the Government of the Republic of Moldova no. 306 of 28.04.2011 (Official Gazette of the Republic of Moldova, 2011). Afterwards, the average value for the entire hive of each of the morpho-productive characters evaluated was calculated.

In order to research the impact of climate change on the vital activity of bee families, the average monthly and annual data of the atmospheric air temperature for the last 11 years (2010-2020) were collected from the nearest Hydrometeorological Station, located in Bravicea, Călăraş district, at a distance of 27 km from the apiary. During this period, for each individual month, Pearson's linear correlation coefficients were calculated between the average monthly temperature of the atmospheric air and the average value per hive of each of the 6 main morpho-productive characters of bee families, such as: prolificacy queens, colony strength, colony overwintering resistance, colony resistance to disease, brood viability and colony honey production. For the months of the first half of the year, the correlation coefficients were calculated between the atmospheric air temperature and the values of the morpho-productive characters of the bee families, evaluated in the same year at the end of June, with the exception of winter resistance, which was evaluated at the end of the month of March.

Given the fact that the climatic factors of the second half of the year no longer influence the morpho-productive characters already evaluated this year in June, the atmospheric air temperature variable from July - December was calculated in correlation with the value of the morpho-productive characters of the families of bees from the following year.

The same correlation coefficients were also calculated for the variable of the average annual temperature of the atmospheric air and the average values per apiary of the above-mentioned 6 morpho-productive characters. Pearson's linear correlation coefficient (r_{xy}) was calculated on the electronic computer in the Files/StatSoft/STATISTICA 12 program. For each correlation coefficient (r_{xy}) separately, the correlation significance criterion (t_r) and the certainty threshold (P) by Student.

The data obtained in the research were statistically processed with the help of the computerized software "STATISTICA - 12" and their certainty was assessed, according to the variational biometric statistics, according to the methods of Плохинский Н.А. (1989).

RESULT AND DISCUSSIONS

The research results demonstrated that the phenomenon of global warming also manifested itself here in the area of the Bravicea Hydrometeorological Station, located near the site of the experimental apiary (Tab. 1).

Table 1 Average atmospheric air temperature recorded at the "Bravicea" Hydrometeorological Station, Călărași district, in the period 2010-2020

Month of the year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	-5.5	-2.6	-3.5	-4.1	-1.4	0.1	-3.1	-5.0	-1.2	-2.4	0.7
February	-0.3	-3.8	-9.8	-0.8	-0.6	0.7	5.2	-0.7	-1.2	2.7	4.4
March	4.3	1.9	3.5	-0.6	7.9	5.2	6.3	8.2	0.8	6.9	7.9
April	10.8	9.6	11.7	11.2	11.2	10.4	13.5	10.5	15.3	10.6	10.7
May	17.3	15.8	17.2	17.6	16.3	17.1	15.3	16.0	18.3	16.7	14.1
June	20.8	19.5	20.6	19.6	18.9	20.9	21.0	21.1	21.2	22.3	21.2
July	22.9	21.1	23.7	19.9	21.9	23.4	22.3	21.8	21.8	21.1	22.9
August	23.7	19.7	20.8	19.9	21.8	22.5	21.3	21.9	22.6	22.0	23.1
September	15.3	16.7	17.1	12.9	16.4	19.4	17.2	17.3	16.5	16.6	19.2
October	7.2	7.7	10.6	9.9	8.6	8.8	8.0	10.3	11.5	11.6	14.1
November	10.8	2.2	4.9	7.2	4.1	6.1	3.9	5.7	2.2	8.3	4.6
December	-2.0	1.7	-5.1	-0.2	0.2	1.9	-0.1	3.6	-0.4	3.1	2.5
Average year	**10.4**	**9.1**	**9.3**	**9.4**	**10.4**	**11.4**	**10.9**	**10.9**	**10.6**	**11.6**	**12.1**

More than that, global warming in this area was much more obvious, compared to the data from the European Commission Report (Cosenquences of climate change, 2018). We found that the average annual temperature of the atmospheric air increased in this area from 10.4°C in 2010 to 12.1°C in 2020, or by 1.7°C (16.3%). If we compare the average air temperature of the first three years (2010-2012) of the research period with the average of the last three years (2018-2020), we find a rather large increase in it from 9.6°C to 11.4°C, or by 1.8°C, which is very much and worrying. Because of this, in the relatively short research period of only 11 years, three terrible droughts occurred in this area: one in 2012, the second in 2015 and the third in 2020.

If we make a comparison with the year 2011 (the year in which the lowest atmospheric air temperatures were recorded), then we can see that the greatest increases in the atmospheric air temperature in the area were recorded in the winter months: in January – with 3.3°C or 26.9% and February – by 8.2°C or 2.1 times; in the first spring month, March – by 6.0°C or 4.1 times; in the last summer month, August – by 3.4°C or 17.3% and in the first autumn month, October – by 6.4°C or 83.1%. From these data we can conclude that winters with low temperatures have practically disappeared. At the same time, spring, summer and autumn temperatures increased excessively.

High air temperatures and severe droughts have had a negative impact on the flora and fauna of nature's ecosystems, especially on the agriculture of this area. We can assume that, if the warming of the air will continue at this rate, we will witness in a few decades the transformation of this area into an arid and desertified one.

Research has shown that air temperature is one of the most important climatic factors that influence the vital activity of Apis mellifera bee families (Tab. 2).

Between this climatic factor and the evolution of the value of the morpho-productive characters of the bee families there are correlative links of different magnitude. The impact of climatic changes in air temperature on bee colonies depends on the time of year.

Table 2 Average indices of the morpho-productive characters of bee families at the Experimental Apiary of the Institute of Zoology in the period 2010-2020

No. do	Year	Prolificity, eggs/24 hours	The power family, kg	Winter hardiness, %	Viability brood, %	Disease resistance, %	Production of honey, kg
1	2010	1583	2.83	80.1	85.1	76.8	38.8
2	2011	1806	2.97	82.5	91.0	89.4	32.8
3	2012	1740	2.37	86.2	88.6	87.4	23.9
4	2013	1661	3.03	91.1	91.0	90.5	35.5
5	2014	1781	3.13	93.3	92.3	91.6	57.4
6	2015	1711	3.04	88.6	95.8	86.3	44.2
7	2016	1371	2.20	84.1	95.7	89.2	31.0
8	2017	1678	2.36	86.8	95.5	92.6	34.2
9	2018	1781	3.14	88.4	95.4	91.7	39.7
10	2019	1716	2.38	71.3	88.1	91.6	49.9
11	2020	1752	2.05	83.4	92.1	91.0	38.8

It was found that the impact of air temperature on the vital activity of bee families is caused both by the average monthly temperatures in some specific periods of the year, and by the annual average temperature of the atmospheric air. The greatest impact on the vital activity of bee families was caused by climatic changes in the atmospheric air temperature in the first half of the year, especially in the months of January, February, April and June (Tab. 3).

Table 3 The correlation coefficient (r_{xy}) between the average monthly air temperature in the first half of the year and the average value of the morpho-productive characters of bee families

Morpho-productive character	$r_{xy} \pm m_r$	t_r	P
t°C air January			
Winter hardiness	0.469±0.275	1.74	<0.1
Queen's prolificity	0.464±0.076	6.11***	<0.001
Power of the family	0.439±0.285	1.54	>0.1
Disease resistance	0.269±0.328	0.82	>0.1
Brood viability	0.495±0.267	1.85	<0.1
Honey production	0.488±0.269	1.81	<0.1
t°C air February			
Winter hardiness	0.015±0.353	0.04	>0.1
Queen's prolificity	-0.594±0.129	2.59*	<0.05
Power of the family	-0.006±0.353	0.01	>0.1
Disease resistance	0.009±0.353	0.03	>0.1
Brood viability	0.511±0.262	1.96*	<0.05
Honey production	0.370±0.303	1.21	>0.1
t°C air March			
Winter hardiness	0.107±0.349	0.31	>0.1
Queen's prolificity	-0.129±0.347	0.37	>0.1
Power of the family	-0.331±0.314	1.05	>0.1
Disease resistance	0.161±0.344	0.47	>0.1
Brood viability	0.449±0.282	1.59	>0.1
Honey production	0.401±0.296	1.35	>0.1
t°C air April			
Queen's prolificity	-0.795±0.130	6.12***	<0.001
Power of the family	-0.603±0.225	2.68*	<0.05
Disease resistance	0.070±0.352	0.20	>0.1
Brood viability	0.182±0.342	0.53	>0.1
Honey production	-0.222±0.336	0.66	>0.1
t°C air May			
Queen's prolificity	0.332±0.314	1.06	>0.1
Power of the family	0.421±0.291	1.45	>0.1
Disease resistance	-0.451±0.282	1.60	>0.1
Brood viability	-0.548±0.247	2.22*	<0.05
Honey production	0.038±0.353	0.10	>0.1
t°C air Iune			
Queen's prolificity	-0.461±0.278	1.66	<0.1
Power of the family	-0.691±0.184	3.76***	<0.001
Disease resistance	-0.350±0.310	1.13	>0.1
Brood viability	0.192±0.341	0.56	>0.1
Honey production	-0.497±0.266	1.87	<0.1

Thus, it was found that, between the average temperature of the atmospheric air in January and the prolificacy of the queens in the bee families, determined at the end of June, a significant positive correlation was found (r_{xy}= 0.464±0.076; t_r=6.11; P<0.001).

This means that, with the increase in air temperature in January, there is an increase in the prolificacy of queens at the end of spring - beginning of summer.

The air temperature in January tends to have a positive influence on the winter resistance of bee colonies (assessed at the end of March), brood viability, as well as honey production, assessed at the end of summer.

More obviously this tendency can be visualized in the diagram (Fig. 1).

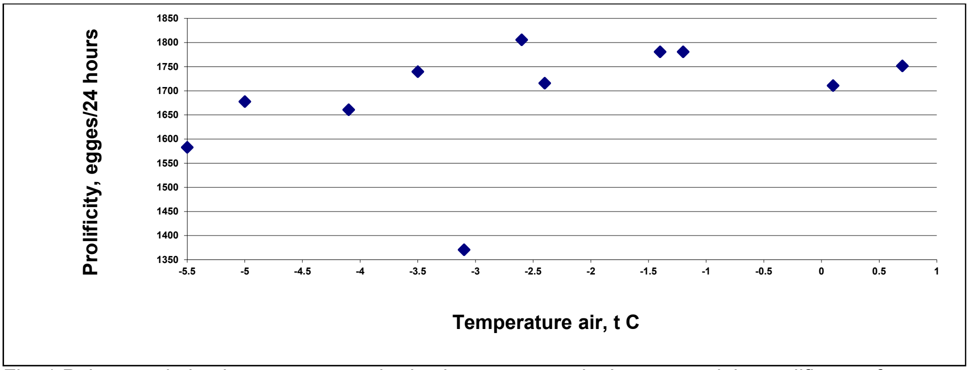

Fig. 1 Point correlation between atmospheric air temperature in January and the prolificacy of queens

The correlation coefficients between these characters are of medium size and between the values of 0.469 - 0.495 (t_r=1.74 – 1.85; P<0.1). At the same time, the research demonstrated that the variability of the air temperature in February has a significant inverse (negative) correlation with the prolificacy of the queens and positive with the viability of the brood, evaluated at the beginning of summer (June) (Fig. 2).

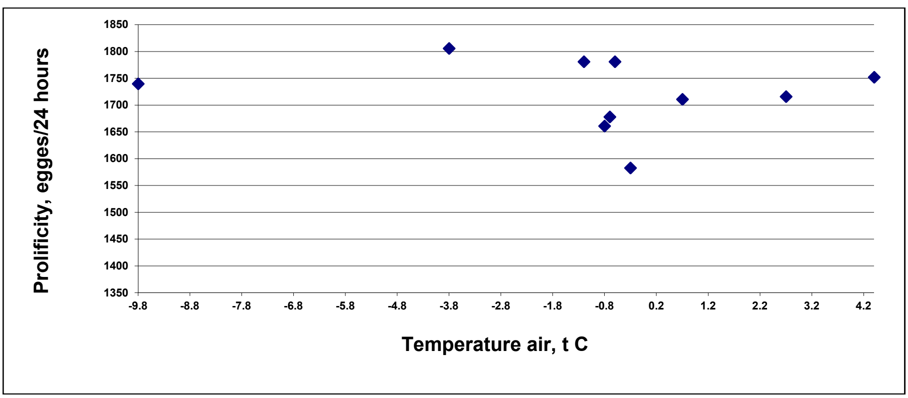

Fig. 2 Point correlation between atmospheric air temperature in February and the prolificacy of queens

The correlation coefficient between these variables is of medium size, but quite significant (r_{xy} = -0.594±0.129; t_r = 2.59; P<0.05 and r_{xy}= 0.511 ± 0.262; t_r=1.96; P<0.05). This means that the higher the air temperature in February, the lower will be the prolificacy of the queens and the higher will be the viability of the brood.

We cannot say about the air temperature in March that it neither influences nor that it does not influence the vital activity of bee families, because the correlation coefficients of this variable with the main morpho-productive characters are not significant, which does not allow us to do some definite conclusions.

Research data demonstrate that the air temperature in April has an obvious impact on the vital reproductive functions of the queen and the development of bee families. Thus, the air temperature in April has a significant negative correlation with the prolificacy of the queen (r_{xy}= -0.795±0.130; t_r=6.12; P<0.001) (Fig. 3).

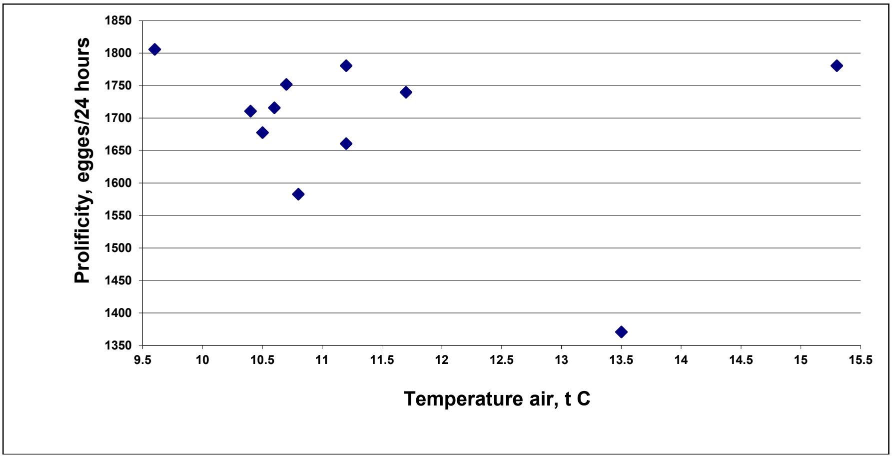

Fig. 3 Point correlation between atmospheric air temperature in Aprilie and the prolificacy of queens

This means that with the increase in air temperature in April there will be a decrease in the prolificacy of the queens at the beginning of the summer, which will have a negative impact on the strength of the bee colony.

The research results showed that the air temperature in April has a significant negative correlation with the strength of the colony (r_{xy}= -0.603±0.225; t_r=2.68; P<0.05).

More obviously this trend can be visualized in the diagram (Fig. 4).

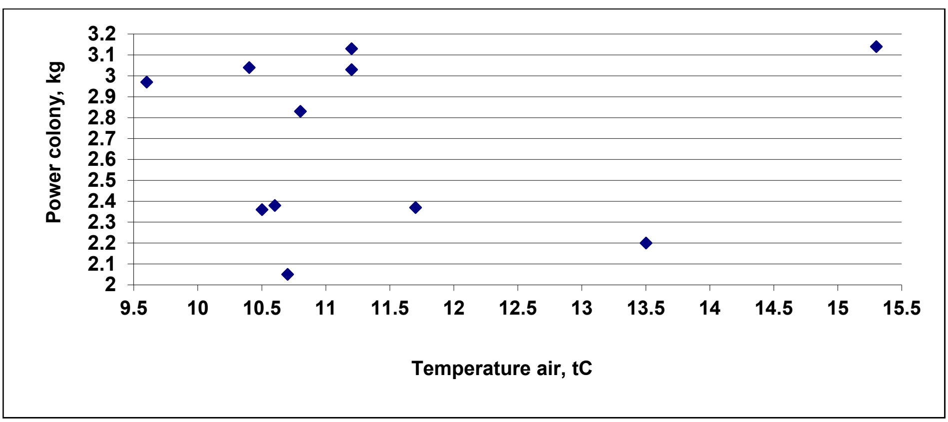

Fig. 4 Point correlation between April atmospheric air temperature and colony power

This means that, with the sudden increase in atmospheric air temperature in April, the strength of the bee colony will decrease. It would seem that this correlation is not adequate, but the correlation coefficient between these two variables is quite significant.

Regarding the climate changes in May, we can say that the air temperature in this month has a negative influence on the viability of the brood. The increase in atmospheric air temperature in May will lead to a decrease in the viability of the brood (Fig. 5).

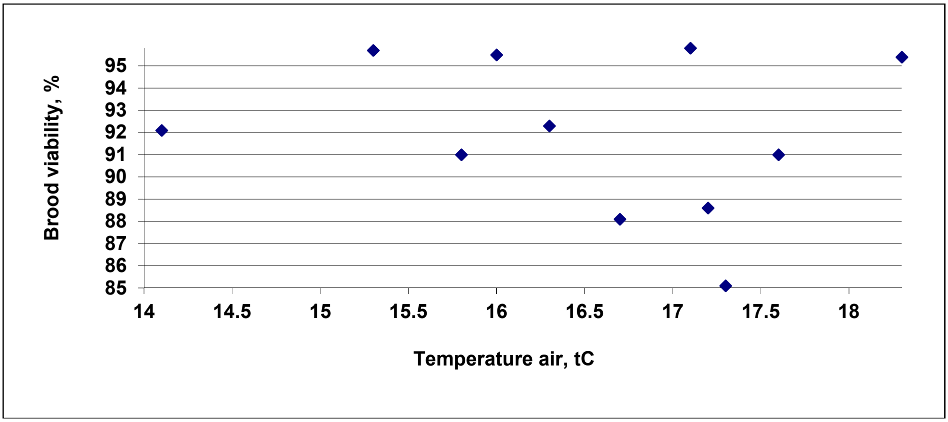

Fig. 5 Point correlation between atmospheric air temperature in May and brood viability

The correlation coefficient between these two variables is significantly negative of medium size and is r_{xy}= -0.548±0.247; t_r=2.22; P<0.05. As for the impact of the air temperature in May on the other morpho-productive characters, we cannot say either that it influences or does not influence the vital activity of bee families, because the correlation coefficients between this variable and the main morpho-productive characters are not significant, which does not allow us to draw any definite conclusions.

It was found that the air temperature in June has a greater impact on the vital activity of bee families. Namely, the air temperature in this summer month has an obviously negative impact both on the reproductive and development functions of bee families, as well as on the ability to accumulate honey production in the nest. Thus, the research data demonstrate that, between the air temperature in June and the power of the family there is a significant negative high-level correlation (Fig. 6).

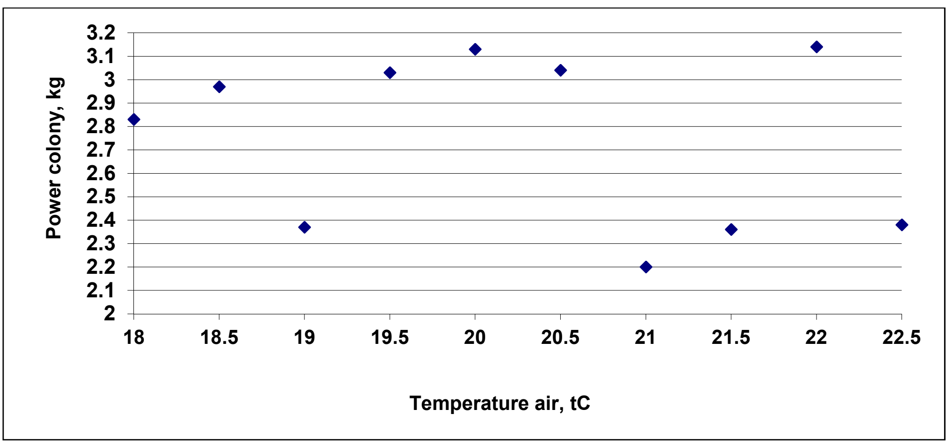

Fig. 6 Point correlation between atmospheric air temperature in June and colony power

The correlation coefficient between these two variables is quite high with the most significant certainty threshold according to Student (r_{xy}=-0.691±0.184; t_r=3.76; P<0.001). The climatic variability of the air temperature in June has a negative correlation tendency both with the prolificacy of the queens (r_{xy}= -0.461±0.278; t_r=1.66; P<0.1) and with the honey production (r_{xy}= -0.497 ±0.266; t_r=1.87; P<0.1). This means that with the increase in air temperature in June there will be a decrease in the strength of bee families and the production of honey accumulated in the nest.

Generalizing the impact of climatic changes in air temperature in the first half of the year, we can conclude that high temperatures in this period, especially in April - June, have a negative impact on the vital activity of bee families.

In nature, the negative impact of air temperature is caused directly, first of all, on honeydew flowers. Under the action of high temperatures, they bloom suddenly in a restricted (short) period, and the removed nectar evaporates quickly, becoming too consistent and inaccessible to bees. Second, excessively high temperatures inhibit the vital activity of nurse and worker bees, which leads to a decrease in the reproductive functions of queens and the picking functions of worker bees.

This conclusion is consistent with some of our previous research (Cebotari et al., 2013) in which it was demonstrated that excessively high temperatures in the spring-summer of a dry year caused a drastic decrease in the value of the morpho-productive indices of bee families.

Starting with the second half of the year, the atmospheric air temperature from July-December can no longer have an impact on the morpho-productive characters previously evaluated (until the end of June). At the same time, the air temperature in the second half of the year can have a direct impact on the vital activity of the bee families related to the consolidation of the power of the colonies and their preparation for the winter, as well as indirectly on the evolution of the value of the morpho-productive characters in the next year.

Analyzing the variability of the atmospheric air temperature in the second half of the previous year in correlation with the evolution of the morpho-productive characters of the bee families evaluated in the first half of the following year, we found that this (air temperature) also has an obvious impact on the activity vital of bee families (Tab. 4).

Table 4 The correlation coefficient between the average monthly atmospheric air temperature in the second half of the year and the value of morpho-productive characters of bee families in the following year

Morpho-productive character	$r_{xy} \pm m_r$	t_r	P
t^0C air Iuly			
Winter hardiness	-0.479±0.272	1.76	P<0.1
Queen's prolificity	-0.531±0.254	2.09	P<0.05
Power of the family	-0.233±0.334	0.70	P>0.1
Disease resistance	-0.045±0.353	0.13	P>0.1
Brood viability	0.157±0.345	0.46	P>0.1
Honey production	-0.548±0.247	2.22	P<0.05
t^0C air August			
Winter hardiness	-0.699±0.181	3.86	P<0.001
Queen's prolificity	-0.146±0.346	0.42	P>0.1
Power of the family	0.040±0.353	0.11	P>0.1
Disease resistance	-0.067±0.352	0.19	P>0.1
Brood viability	0.388±0.300	1.29	P>0.1
Honey production	-0.206±0.339	0.61	P>0.1
t^0C air September			
Winter hardiness	-0.494±0.267	1.85	P<0.1
Queen's prolificity	-0.711±0.175	4.06	P<0.001
Power of the family	-0.606±0.224	2.71	P<0.01
Disease resistance	-0.139±0.347	0.40	P>0.1
Brood viability	0.384±0.301	1.27	P>0.1
Honey production	-0.684±0.188	3.64	P<0.001
t^0C air October			
Winter hardiness	0.768±0.145	5.30	P<0.001
Queen's prolificity	-0.063±0.352	0.18	P>0.1
Power of the family	0.517±0.259	2.00	P<0.05
Disease resistance	0.404±0.296	1.36	P>0.1
Brood viability	0.186±0.341	0.54	P>0.1
Honey production	0.513±0.261	1.97	P<0.05

t^0C air Noivember			
Winter hardiness	-0.264±0.329	0.80	P>0.1
Queen's prolificity	0.108±0.349	0.31	P>0.1
Power of the family	0.394±0.299	1.32	P>0.1
Disease resistance	0.222±0.336	0.66	P>0.1
Brood viability	-0.040±0.353	0.11	P>0.1
Honey production	0.260±0.330	0.79	P>0.1
t^0C air December			
Winter hardiness	-0.223±0.337	0.66	P>0.1
Queen's prolificity	-0.100±0.350	0.28	P>0.1
Power of the family	-0.289±0.324	0.89	P>0.1
Disease resistance	-0.061±0.352	0.17	P>0.1
Brood viability	0.402±0.296	1.36	P>0.1
Honey production	-0.055±0.353	0.16	P>0.1
t^0C air average Year			
Winter hardiness	-0.528±0.255	2.07	P<0.05
Queen's prolificity	-0.440±0.285	1.54	P>0.1
Power of the family	-0.295±0.323	0.91	P>0.1
Disease resistance	0.178±0.342	0.52	P>0.1
Brood viability	0.833±0.108	7.71	P<0.001
Honey production	-0.121±0.348	0.35	P>0.1

Thus, the atmospheric air temperature in July has a tendency to have a negative impact on winter resistance (r_{xy}= -0.479±0.272; t_r=1.76; P<0.1) and a significant negative impact on queen prolificacy (r_{xy}= -0.531±0.254; t_r=2.09; P<0.05), as well as with honey production the following year (r_{xy}=-0.548 ±0.247; t_r=2.22; P<0.05) (Fig. 7).

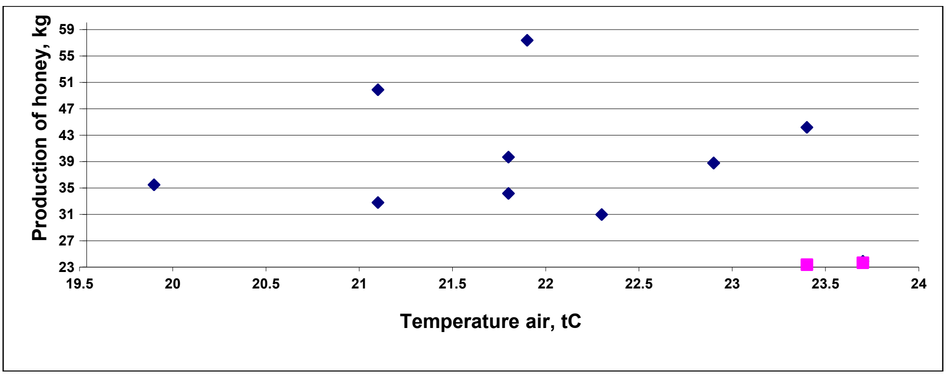

Fig. 7 Point correlation between atmospheric air temperature in July and honey production

This means that, with the increase in atmospheric air temperature in the month of July in the apiary area, there will be a tendency to decrease the winter resistance of the bee colonies, as well as a significant decrease in the prolificacy of the queens and the production of honey accumulated in the nest in next year.

In the month of August, climate change by increasing the atmospheric air temperature has a significant negative impact on the winter resistance of bee families in the following year (Fig. 8).

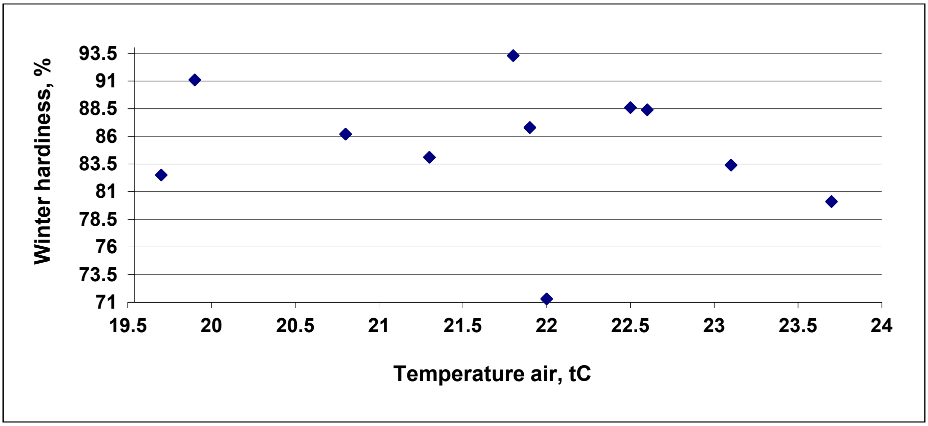

Fig. 8 Point correlation between atmospheric air temperature in August and winter hardiness

The correlation coefficient between these two variables is of a high level and quite significant, of the highest certainty threshold according to the probability theory of forecasts without error according to Student (r_{xy}= -0.699 ±0.181; t_r=3.86; P<0.001). This means that the higher the air temperature in August, the lower the winter resistance of bee colonies next year.

About the variability of the value of the other morpho-productive characters of the bee families, we cannot say either that it was influenced or that it was not influenced by the atmospheric air temperature in August, because the correlation coefficient values between these variables were not significant.

At the same time, the climatic change of atmospheric air temperature in September has an obvious impact on several morpho-productive characters of the vital activity of bee families in the following year. Thus, the atmospheric air temperature in this autumn month has a significant negative impact on the prolificacy of queens (r_{xy}=-0.711±0.175) (Fig. 9).

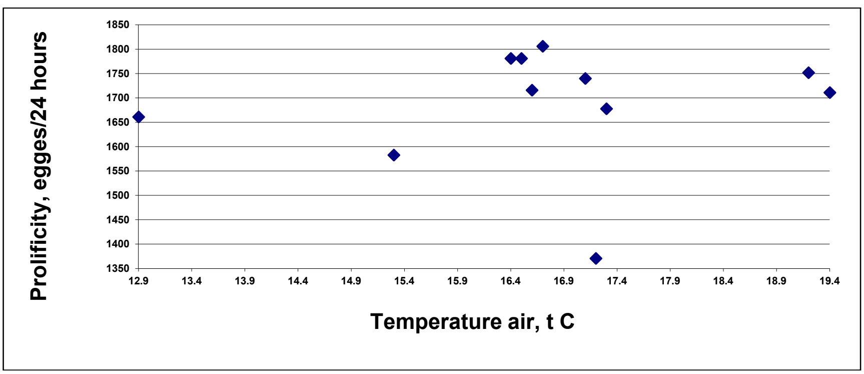

Fig. 9 The punctual relationship between the atmospheric air temperature in September and the prolificacy of queens

At the same time, air temperatures in September have a tendency to have a negative impact on the winter resistance of bee colonies (r_{xy}= -0.494±0.267; t_r=1.85; P<0.1) and a significant negative impact on the strength of bee families bees (r_{xy}= -0.606±0.224; t_r=2.71; P<0.01). But, the temperatures of this month have the greatest negative impact on the production of honey accumulated in the nest in the following year (r_{xy}=-0.684±0.188; t_r=3.64; P<0.001) (Fig. 10).

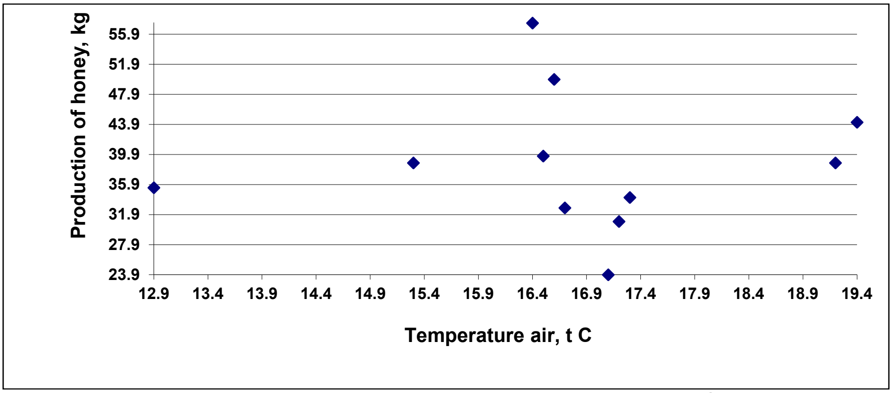

Fig. 10 Point correlation between atmospheric air temperature in September and honey production

This means that, with the rise in atmospheric air temperature in September, there will be a decrease in the following year's resistance to wintering, the prolificacy of the queens, the strength of the colonies and their honey production.

A completely different (opposite) influence on the vital activity of bee families has the climatic changes of the atmospheric air temperature in the month of October. It was found that the increase in atmospheric air temperature in this autumn month has a beneficial influence on the main morpho-productive characters of the bee families. High temperatures in this month correlate significantly positively with the winter resistance of bee colonies (rxy= 0.768±0.145; tr=5.30; P<0.001) (Fig. 11).

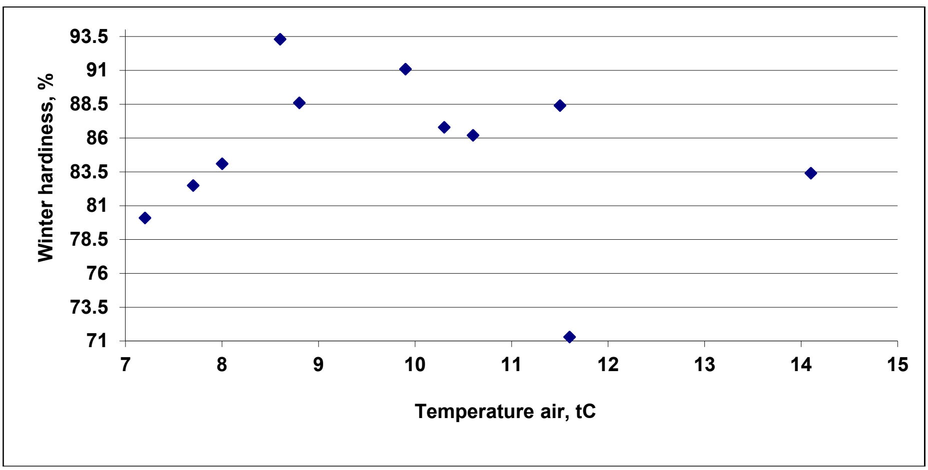

Fig. 11 Correlation curve between atmospheric air temperature in October and winter hardiness

Therefore, the high temperatures in October will contribute to the successful wintering of bee families and, respectively, to their better development in the spring of next year.

Temperatures in this autumn month correlate significantly positively with the strength of bee colonies in the following year (r_{xy}= 0.517±0.259; t_r=2.00; P<0.05) (Fig.12).

In addition, the air temperature in October has an obvious trend of positive correlation with the honey production of the bee families in the following year (r_{xy}= 0.513±0.261; t_r=1.97; P<0.05).

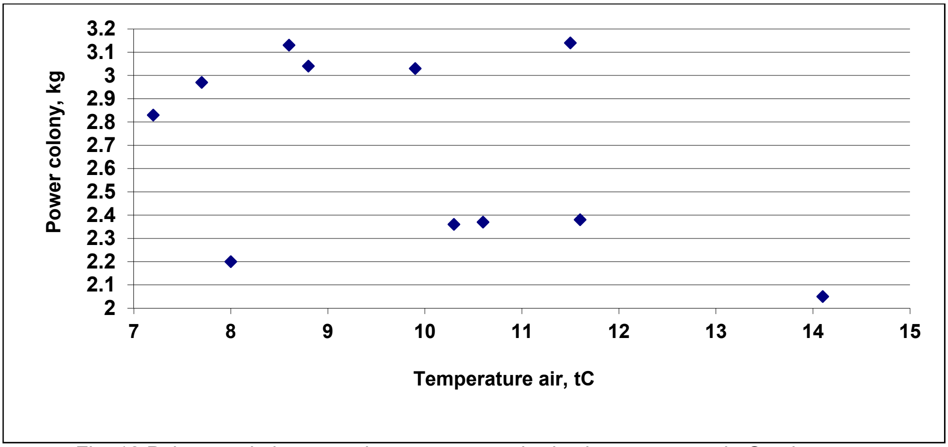

Fig. 12 Point correlation curve between atmospheric air temperature in October and colony power

This means that, with the increase in atmospheric air temperature in the month of October in the current year, we will have an improvement in the value of the main morpho-productive characters of bee families in the following year.

About the climatic changes of atmospheric air temperature in the months of November and December, we can neither affirm nor deny that they somehow influence the variability of the value of the morpho-productive characters of bee families, because the correlation coefficients between these variables are insignificant, which does not allow us to we draw some conclusions.

Regarding the climatic change of the average annual temperature, we found that it has a significant impact only on the variability of the value of some morpho-productive characters of the bee families from the following year, such as the viability of the brood (Fig. 13).

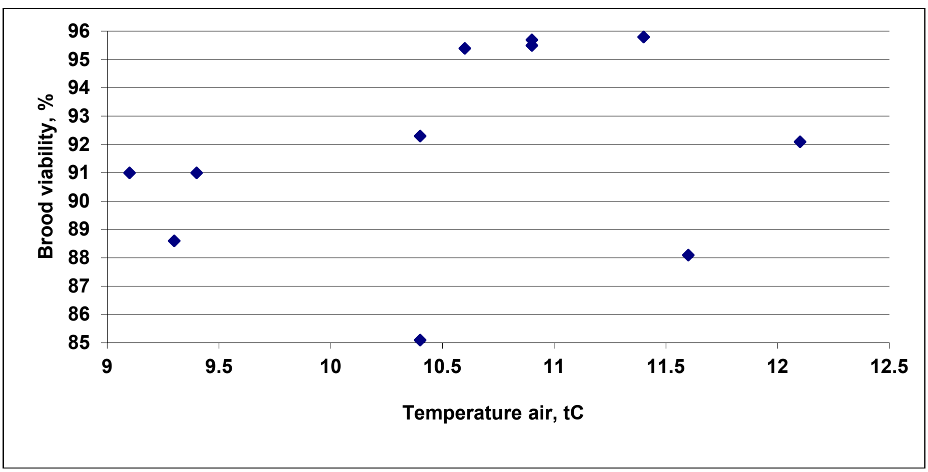

Fig. 13 Point correlation curve between the annual mean atmospheric air temperature and brood viability

Thus, the average annual temperature has a significantly positive correlation, at a very high level, with the viability of the next year's brood (r_{xy}= 0.833±0.108; t_r=7.71; P<0.001). At the same time, the average annual temperature correlates significantly negatively with the colony's resistance to wintering (r_{xy}= -0.528±0.255; t_r=2.07; P<0.05). This means that, with the increase in the average annual temperature of the atmospheric air, we will witness a reduction in the winter resistance of bee families (assessed in March) and an increase in brood viability, assessed in June the following year.

Therefore, generalizing the data of the correlative links between the climatic changes of atmospheric air temperature and the values of the main morpho-productive characters of bee families we can conclude that they (climate changes) have a significant influence on the vital activity of bee colonies. The variability of atmospheric air temperature in different months of the year influences the development of the morpho-productive characters of bee families differently. More than that, the climatic changes of the atmospheric air temperature in the first half of the year directly influence the variability of the value of the morpho-productive characters, evaluated until the end of June, and the air temperature in the months of July - December indirectly influence the variability of their value from next year.

Knowing the particularities of the impact of climatic changes of atmospheric air temperature on the variability of the value of the morpho-productive characters of the bee families in different concrete periods (months) of the year will allow beekeepers to undertake certain measures to mitigate the negative impacts, by applying special care procedures and targeted additional feeding of bee colonies according to specific times of the year.

CONCLUSIONS

1. The winter resistance of *Apis mellifera* bee colonies is positively influenced by the atmospheric air temperature in October last year and January this year (r_{xy} = 0.768 and 0.469). At the same time, the high temperatures of the atmospheric air in the months of July, August and September have a negative influence on the winter resistance of bee families (r_{xy} = -0.479; -0.0.699 and -0.494).

2. The prolificacy of queens is positively influenced only by January temperatures (r_{xy} = 0.464). High atmospheric air temperatures in February, April and June have a negative impact on the prolificacy of queens (r_{xy} = -0.594; -0.795; -0.691). High temperatures in the second half of the year, especially in the months of July and September, negatively influence the prolificacy of queens the following year (r_{xy} = -0.531; -0.711).

3. The strength of bee families is negatively influenced by the atmospheric air temperatures in April and June (r_{xy} = -0.603; -0.691). The high temperatures in September have a negative impact (r_{xy} = -0.606), and those in October have a positive impact (r_{xy} =0.517) on the strength of the colony the following year.

4. Air temperatures in January and February have a positive influence (r_{xy} = 0.495; 0.511), and those in May have a negative influence (r_{xy} = -0.548) on the viability of the bee brood. Overall, the average annual air temperature has a positive influence on brood viability (r_{xy} = 0.833).

5. Honey production is positively influenced by the atmospheric air temperature in January (r_{xy} = 0.488) and negatively – by the atmospheric air temperature in June (r_{xy} = -0.497). At the same time, the atmospheric air temperatures in July and September have a negative impact (r_{xy} = -0.548; -0.684), and those in October - a positive impact (r_{xy} = 0.513) on the honey production of the bee families in the following year.

ACKNOWLEDGEMENTS

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