RESEARCH ARTICLE

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Study of the trends in honey productivity and honey bee mortality under hydrothermal conditions in Eastern Bulgaria during the period 2008-2020

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ABSTRACT

In recent decades, many studies have focused on climate change and its impact on the agricultural sector. With their activity, honey bees not only have a significant impact on the yields of agricultural crops but also give us one of the most unique foods on earth - honey. In this study, data on honey production and honey bee mortality, published for the free access in the reports of the Ministry of Agriculture and Food in Bulgaria, were analyzed. Using the non-parametric Mann-Kendall test, the significance and direction of trends in eastern Bulgaria for the period 2008-2020 were assessed. No significant trends were found in honey yields for this period. There is a negative significant trend in honey bee mortality for the whole country, a positive trend in losses from pesticides and diseases in the Southeast region, and a significant decrease in winter mortality. Also, the authors explore the hypothesis that the influence of temperature and precipitation on honey yields can be indicated by hydrothermal indices. In this case, moderate, negative correlations were observed between the annual value of the Ped index and yields in the two studied areas.

Key words: Ped index, honey yield trends, honey bees mortality, Eastern Bulgaria, *Apis mellifera*

Introduction

Cultivation of beehives is an essential part of the agricultural sector, capable of providing good income in poor areas, where agriculture is less developed or suitable soil conditions are lacking. Beehives and their correct placement for bee pollination can significantly improve both the yields and the quality of plant agricultural production. A study of whether climate warming could lead to indirect effects on pollination was done by Rader et al. (2013). Their results show that under the IPCC's most extreme scenario (A1F1), pollination services performed by managed honey bees could decline by 14.5% by 2099. In conditions of climate change, both forage sources and honey bees themselves are exposed to more and more stress factors and their complex impact (Ilieva et al., 2020; 2021). This is the cause of partial loss, health status deterioration, or death of entire bee colonies. Many research works, concerning Europe and Bulgaria, note an increase in the number and frequency of extreme phenomena (Matev, 2020; Malcheva et al, 2022; Nikolova et al, 2022). Weather conditions may be a factor in bee susceptibility to disease. The autumn hydrothermal conditions, the warmer and snowless winters, and the crucial spring colds may be the reason for a change in winter bee mortality. The unfavorable phenomena of meteorological origin result in a greater need to use pesticides, which poison the bee forage and the bees themselves. All this seriously worries the scientific community and provokes research, related to the topic of vital bee activity, pollination and weather conditions, and climate (Rader et al., 2013). Bee activity is in relation to the meteorological elements - temperature and precipitation. Therefore, temperature and precipitation are the most important predictors in modeling and predicting bee behavior and honey yields (Calovi et al., 2021). The latter authors use the complex, non-linear relationships between the factors to predict and map winter survival in managed *Varroa* mite populations. Some authors link the effect of climate change on crop yield to changes in honey yield. Others note that the proportion of visits by honey bees increases with higher overall temperature and less seasonality. Some authors state that the analysis of how bee visitation correlates with environmental variables reveals a relationship with both climatic and geographic predictors. In Bulgaria, a new study, making a comparative analysis of bee colony losses was done by Ilieva et al. (2021). The authors focus on a detailed analysis of mortality in bee colonies for

2019/20 - the second warmest year in our country after 1930, as well as on some risk factors, based on a survey of over 6,800 bee colonies in Bulgaria. Research related to the loss of bee colonies in the record-warm year 2020 for 37 countries was done by (Gray et al., 2022). Among the leading causes of bee loss in Europe is pesticide poisoning, as stated by (Ivanova, 2018; Migdal et al., 2018; Hayasaka et al., 2019). Therefore, many authors classify the presence of pollen pasture, requiring plant protection, as a potential risk factor for the loss of bee colonies (Gray et al., 2019; Tomljanovic et al., 2020; Ilieva et al., 2021). In Bulgaria, the loss of bee colonies and the complex of reasons for it have been only partially studied (Ivanova & Petrov, 2010; Ilieva et al., 2021). The high temperatures are the reason for the shorter vegetation period in the bee forage, as well as for the mass-flowering dates shift, concerning individual crops and regions. The combination of the different hydrothermal conditions affects honey yields. On the one hand, the wetter and cooler weather is the reason for the longer flowering, and on the other hand, precipitation affects bee activity and flight. The present study is an attempt to make an assessment of the problems, despite the great heterogeneity of the data and the grouping not by climatic regions but by administrative ones. It focuses on the significance and direction of the trends in bee mortality for various reasons. Trends have been calculated and correlations between major meteorological elements and indices and the yields in the individual administrative regions, have been sought for. The period under study is 2008-2020.

Materials and Methods

Bulgaria is situated on the Balkan Peninsula in South-Eastern Europe in transition between two climatic zones – moderate-continental and Mediterranean. Despite its small territory of 111 000 km^2, its local peculiarities contribute to distinguishing regions and subregions with diverse climatic characteristics. The amount of precipitation varies from 1000 mm down to 500 mm in certain parts of the Upper Thracian lowland. Precipitation maxima in winter are in the regions of the Black Sea coast and some southeastern parts, and in summer - in the rest of the country. For hydrothermal assessment, this study uses data from 17 representatives of the country’s meteorological stations from the National Institute of Meteorology and Hydrology (NIMH) network. Data on the average monthly air temperature and the monthly amount of precipitation for the last decade or specifically 2008 - 2021, publicly available in the monthly bulletins of NIMH for the respective years, were selected. For the purposes of the study, the Ped drought index (Ped, 1975) was calculated,

$$I_{Ped} = \frac{\Delta T}{\sigma_T} - \frac{\Delta P}{\sigma_P} \quad (1)$$

where ΔT and ΔP are the deviations in the annual mean air temperature (°C) and the total annual rainfall (mm); σT is the standard deviation of the temperature (°C); σP is the standard deviation of the precipitation (mm).

Data from a survey implemented on the model of the Ministry of Agriculture and Food were used for the purposes of this study. The survey aims at determining the number of bee colonies and the amount of honey, produced by calendar years for the period 2008-2020, as well as at collecting data about the number of lost bee colonies during the studied period.

The study uses the country's administrative division into six districts (Figure 1) as follows: North-West district: Vidin, Vratsa, Montana, Lovech, Pleven; North-Central district: Veliko Tarnovo, Gabrovo, Razgrad, Ruse, Silistra; North-East district: Varna, Dobrich, Targovishte, Shumen; South-East district: Burgas, Sliven, Yambol, Stara Zagora; South-West district: Blagoevgrad, Kyustendil, Pernik, Sofia-city, Sofia region; and South-Central district: Kardzhali, Pazardzhik, Plovdiv, Smolyan, Haskovo.

Figure 1. *Administrative areas of Bulgaria.*

The Mann–Kendall test is applicable to detect a monotonic trend of a time series. Sen's method uses a linear model to estimate the slope of the trend, while the variance of the residuals must be constant over time (Salmi et al., 2002). For data processing, the Excel template MAKESENS, Finnish Meteorological Institute (Salmi et al., 2002), was applied. The software performs: testing for the presence of monotonic increase or decrease by the non-parametric Mann-Kendall test and calculating the slope of a linear trend, estimated with the non-parametric Sen method (Gilbert, 1987) at statistical significance levels of 0.001, 0.01, 0.05, and 0.1. Trends were searched for by the non-parametric

Mann-Kendall test in the series of precipitation and temperature. The relationship between honey production and climate was assessed by the Ped index (Ped, 1975) and average annual air temperature using the Pearson correlation method.

Results

Honey bees synchronize their activities with the phenological development and the flowering season of the plants. Meteorological elements such as precipitation and temperature determine the conditions for the development of bee forage (Figures 2 and 3).

A significant upward trend in temperature is observed. Precipitation also registers a positive trend, which, for the studied period 2008-2020 is not statistically insignificant (Table 1).

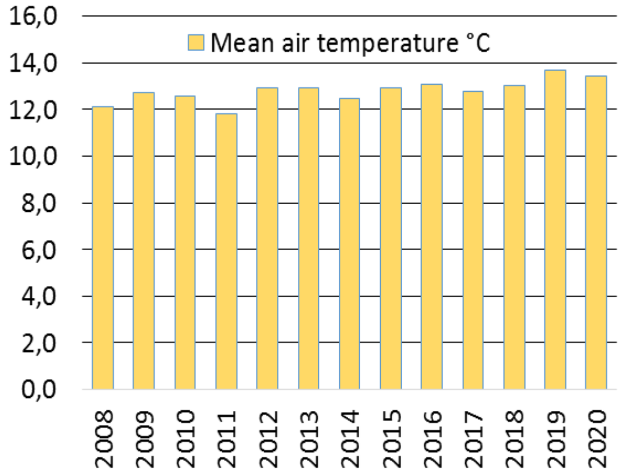

Figure 2. *Mean air annual temperature (°C) for the study period.*

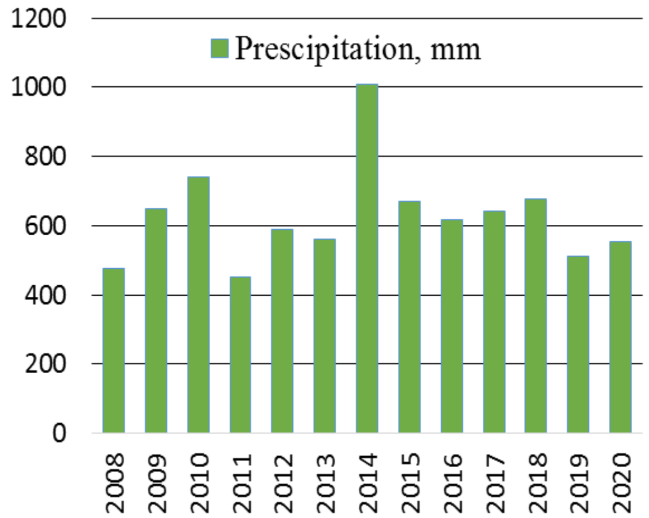

Figure 3. *Total precipitation (mm) for the study period*

The honey bee mortality per year, indicated by the beekeepers, is between 20% и 4.9%. The death rate was the highest in the driest 2011 and the lowest in 2016. A general negative trend is noted, significant at level 0.01 (Table 2). From 2013 to 2020, the honey bee mortality rate in the country is below 10% (Figure 4).

As a result of biotic and abiotic factors, mortality in honey bees for the study period is observed, the distribution of which is shown in Figure 5. The highest 44% of bee hives have died due to „unidentified" reasons. This fact must show that there are inaccuracies in the methodology, which need to be clarified. The next 22.5% of the hives died from poisoning with pesticides. The data report 19.5% of hives, died of

Table 1. *Slopes (Q) and their statistical significances (SS) for mean annual temperature and total annual precipitation during the study period.*

Mann-Kendall trend			**Sen's slope estimate**	
Factors	Test Z	Signific.	Q	Qmin99
Mean T°C	2.41	*	0.07	-0.01
Precipitation	0.55	NS	6.63	-22.24

Table 2. *Slopes (Q) and their statistical significances (SS) for total bee mortality during the study period.*

Mann-Kendall trend			**Sen's slope estimate**
Total bee mortality	Test Z -2.63	Signific. **	Q -0.56

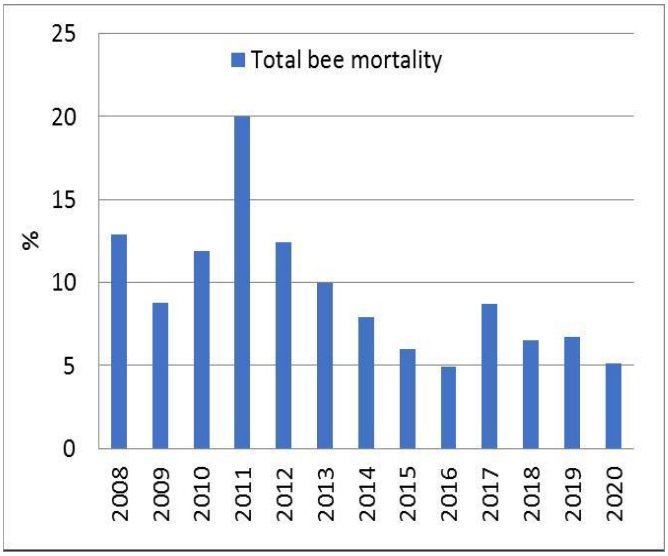

Figure 4. *Annual distribution of honey bee mortality in the country for the period 2007–2020.*

diseases in total for the country, and the lowest 14.7% are related to winter mortality.

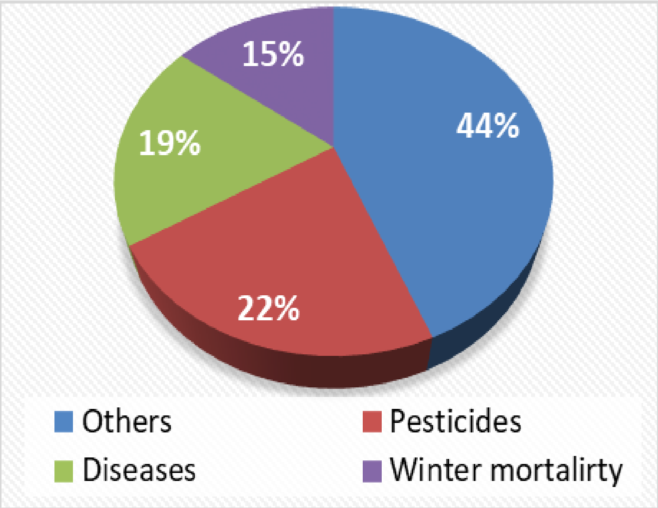

Figure 5. *Honey bee mortality distribution by types in %. Source: Agrostatistics. 2008-2020. Ministry of Agriculture, Food and Forestry.*

The variance in yields shows differences in the studied regions. They are lower in the warmest years compared to those, having values around the average. There is no explicit correlation between the wet years and the years with the highest honey production (Figure 6).

A statistical evaluation of the honey yields shows that there is no significant trend both for the country (Table 3), and in the two regions under study (Tables 4 and 5). In winter mortality the trend is negative with a significance level of 0.05. The trend in pesticide poisoning is best expressed, as in Bulgaria it significantly (0.01) increased during the period 2008-2020.

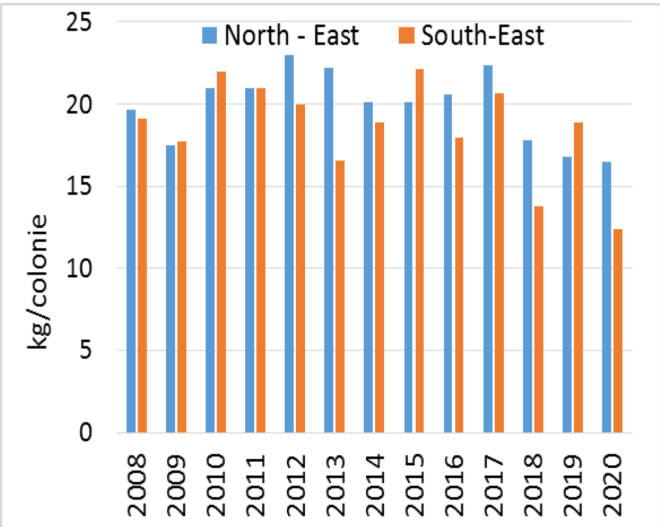

Figure 6. *Average honey yield in South-East and North-East beekeeping regions.*

DISCUSSION

The data about the mean air temperature in this study undoubtedly show statistically significant warming (Table 1) across the entire country.The trends in the stations in both North and South Bulgaria have a level of significance of 0.05.As it concerns the precipitations, in the studied period they show a statistically insignificant increase.

Table 3. *Slopes (Q) and their statistical significances (SS) for yield, diseases, winter mortality (Bulgaria), and pesticides during the study period.*

Bulgaria, Mann-Kendall trend		**Sen's slope**	
		Yield	
n	**Test Z**	**Signific.**	**Q**
14	0.00	NS	0.00
		Diseases	
14	2.19	*	0.95
		Winter mortality	
14	-1.97	*	-1.04
		Pesticides	
14	3.28	**	2.27

Table 4. *Slopes (Q) and their statistical significances (SS) for yield, diseases, winter mortality (Southeast), pesticides during the study period.*

Southeast, Mann-Kendall trend		**Sen's slope**	
		Yield	
n	**Test Z**	**Signific.**	**Q**
14	-0.25	NS	-0.03
		Diseases	
14	1.42	NS	1.01
		Winter mortality	
14	-2.96	**	-1.25
		Pesticides	
14	3.39	***	3.25

Table 5. *Slopes (Q) and their statistical significances (SS) for yield, diseases, winter mortality (Northeast), pesticides during the study period.*

Northeast, Mann-Kendall trend		**Sen's slope**	
		Yield	
n	**Test Z**	**Signific.**	**Q**
14	0.10	NS	0.03
		Diseases	
14	1.31	NS	0.73
		Winter mortality	
14	0.22	NS	0.15
		Pesticides	
14	1.09	NS	1.18

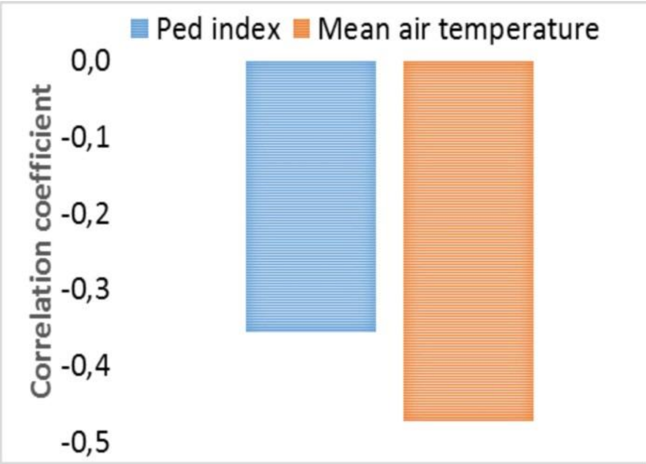

Figure 7. *Coefficient of correlation between the Ped index annual value, mean air temperature and honey production in Bulgaria.*

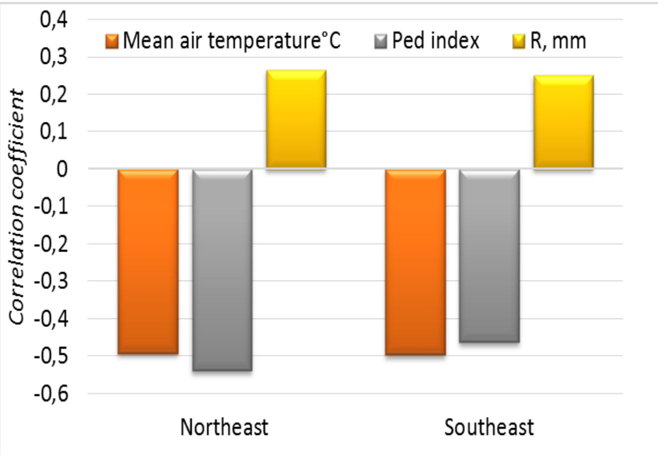

Figure 8. *Coefficient of correlation between the mean air temperature, total amount of precipitation, Ped index and honey yield in Southeast and Northeast regions.*

In this case, a change in the hydrothermal conditions can be anticipated as a result of the warming. Both bee activity and the flowering season – its beginning, end, and duration – are affected by temperature and precipitation. The bee pasture is formed by both natural vegetation and agricultural areas. The sunflower areas in the Northeast region constitute 21.9% of the cultivated sunflower in the whole country (Agricultural Report, 2021). The rapeseed areas are about 152 800 hectares, with the Southeast region having the most of the recultivated areas - 39% (Agricultural Report, 2021). The Southeast region occupies the leading place in fruit production - 26.3% of the country's, with 44.8% peaches and 39% cherries. In raspberry production, the highest share belongs to the Northeast region. The Ped coefficient is an index of dryness, with negative values indicating wet periods and positive values for dry periods.

Our study shows a good correlation between honey yield and hydrothermal conditions for the entire calendar year, expressed in terms of the Ped index, and between honey yield and mean air temperature for the entire country. The correlation coefficient between honey production and the annual value of the Ped index is r = (-0.4). The correlation coefficient between honey yield and mean annual temperature is r = (-0.5). Not only the presence or absence of a correlation between these two variables is indicated with the help of the Pearson correlation coefficient, but it also shows the exact extent to which they are related, as well as the direction of the relationship, i.e., whether the correlation between them is negative or positive. The calculations show that a moderate correlation is found between the honey yield and the Ped coefficient r = (-0.4) and a significant one between the yield and the air temperature r = (-0.5). The Ped coefficient is an index of dryness with negative values indicating wetter periods and positive values - draughts. In this case, the bigger amounts of precipitation throughout the year, including the ones, used for forming a water reserve in spring, have a positive effect on the honey yield. A large part of the bee pasture consists of oil-yielding plants and orchard cultures, as well as of spring species such as sunflower, which suggests the participation of winter precipitation to replenish the productive reserves in the soil. The yields are better at Ped index values close to and slightly below 0, and at temperatures around the average. High temperatures above 13.0°C, over-wetting, and dry periods lead to a decrease in honey yields. The results of these parameters in two agroecological regions are slightly more precise, with the degree of correlation increasing from moderate to significant, and the direction remaining negative. The correlation coefficient between the Ped index and the honey yield in the Southeast region is e r = (-0.5), and in the Northeast it is r > (-0.5). The correlation between yield and temperature for both regions is r = (-0.5). In contrast to temperature, the total amount of precipitation correlates slightly positively with the honey yields. Some studies state that the hydrothermal values in summer have the most significant impact on bee mortality (Calovi et al., 2021). No quantitative relationship was made in our study but drought, in any case, leads to greater use of pesticides and affects both the bee health status and their supplies for wintering. For the conditions of Bulgaria, a negative significant trend in bee mortality (0.05) is observed in the period 2008-2020. After the year 2013, it permanently stays below 10%. In general, pesticide poisoning is the leader in the country, followed by diseases and winter mortality, and this ranking does not include mortality from "undetermined causes" or others. All these three parameters show significant trends for the country, as a whole. Mortality due to diseases significantly increases for the entire country (0.05), which may be a result of the warm weather. Winter mortality shows a significant decrease (0.01). Some studies on honey bee winter survival use the weather and the predictive power of the meteorological elements with respect to winter survival (Calovi et al., 2021). Winter mortality exhibits wide variability, but the roles of the landscape and the meteorological factors have not been well studied and understood yet (Seitz et al., 2015; Brodschneider, et al., 2018). Bee colonies remain active in winter and maintain a temperature between 24 и 34 °C in their hives by forming a thermoregulatory cluster (Heinrich, 1981). Their winter survival depends on the food reserves collected in autumn, and on the status of the wintering bees. The latter live for a few months in contrast to those, in the active season, whose lifespan is only a few weeks. All types of factors, which undermine the ability of bees to collect and store sufficient amounts of food in summer and autumn or thermoregulate effectively in winter, or can reduce the lifespan of winter bees, may contribute to bee colony mortality. In this case, winter mortality can be related to some diseases or parasites such as the *Varroa* mite (Morawetz et al., 2019), to the quality of the collected honey, to the meteorological factors in spring, summer, autumn, and winter, to the onset of egg laying (oviposition) and to the contribution of new forage to the beehives (Switanek et al., 2017). A significant decrease (0.05) in winter mortality in the entire country was observed in this study. In the Southeast region winter mortality is significant at a level of 0.01. Pesticide poisoning is the leading cause of bee mortality. The results show that the regions with intensive agricultural activities in most of the country, especially large areas of orchard cultures, rapeseed, sunflower, and essential oil crops are risky in terms of pesticide poisoning, which correlates with other research works on bee mortality in the country (Ilieva et al., 2021). Nevertheless, there are intensive regions (such as the Northeast one), where the trend is insignificant.

CONCLUSIONS

A good impression is made by the fact that for the period 2008-2020 the total bee death rate in the country shows a significant negative trend, and after the year 2013 it falls down below 10 %. No significant trends in honey production are observed for the entire country, including for the South-east and northeast regions. The results show the leading role of poisoning by pesticides and a positive significant trend, which is indirectly related to climate change and the increasing need for treating agricultural crops. There is also a positive significant trend in bee losses from diseases in the country, as a whole, and in the North-Central and South-West regions as well, which Is helped by the high summer temperatures and droughts in the last decade of the 21st century. Negative significant trends in winter mortality are reported in the Southeast and for the entire country. Risky factors are both the unfavorable phenomena of meteorological origin in spring, summer, autumn and winter, as well as the type of plant-protective activities for agricultural crops. A moderate negative correlation is observed between the Ped index (an index for hydrothermal conditions evaluation) and the average temperature on an annual basis. The two studied regions show great similarity in the correlations r>(-0.5), with a slight prevalence of the hydrothermal conditions in the Northeast region and dominance of the temperature factor in the Southwest region. This indicates that better humidification and lower temperatures are significant factors in honey production.

References

Agricultural Report, 2021. https://www.mzh.government.bg/media/filer_public/2021/12/07/ad_2021.pdf

Agrostatistics. 2008-2020. Ministry of Agriculture, Food and Forestry. Beekeeping in Bulgaria. Retrieved from mzh.government.bg.

Brodschneider R, Gray A, Adjlane N, Ballis A, Brusbardis V, Charrière JD, Chlebo R, Coffey MF, Dahle B, de Graaf DC, Dražić MM, Evans G, Fedoriak M, Forsythe I, Gregorc A, Gręda U, Hetzroni A, Kauko L, Kristiansen P, Martikkala M, Martín-Hernández R, Medina-Flores CA, Mutinelli F, Raudmets A, Ryzhikov VA, Simon-Delso N, Stevanovic J, Uzunov A, Vejsnæs F, Wöhl S, Zammit-Mangion M, Danihlík J. 2018. Multi-country loss rates of honey bee colonies during winter 2016/2017 from the COLOSS survey. J. Apic. Res. 57, 452–457.

Calovi M, Grozinger CM, Miller DA, Goslee SC. 2021. Summer weather conditions influence winter survival of honey bees (*Apis mellifera*) in the northeastern United States. Sci Rep 11: 1553.

Gajger IT, Kosanović M, Oreščanin V, Kos S, Bilandžić N. 2019. Mineral content in honeybee wax combs as a measurement of the impact of environmental factors. Bull. Environ. Contam. Toxicol. 103: 697-703.

Gilbert RO. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York

Gray A, Brodschneider R, Adjlane N, Ballis A, Brusbardis V, Charrière JD, Chlebo R, Coffey MF, Cornelissen B, da Costa CA, Csáki T, Dahle B, Danihlík J, Dražić MM, Evans G, Fedoriak M, Forsythe I, de Graaf D, Gregorc A, Johannesen J, Kauko L, Kristiansen P, Martikkala M, Martín-Hernández R, Medina-Flores CA, Mutinelli F, Patalano S, Petrov P, Raudmets A, Ryzhikov V A, Simon-Delso N, Stevanovic J, Topolska G, Uzunov A, Vejsnaes F, Williams A, Zammit-Mangion M, Soroker V. 2019. Loss rates of honey bee colonies during winter 2017/18 in 36 countries participating in the COLOSS survey, including effects of forage sources. J. Apic. Res. 58(4): 479-485.

Gray A, Noureddine A, Arab A, Ballis A, Brusbardis V, Douglas A B, Cadahía L, Charrière J-D, Chlebo R, Coffey MF, Cornelissen B, da Costa CA, Danneels E, Danihlík J, Dobrescu C, Evans G, Fedoriak M, Forsythe I, Gregorc A, Arakelyan II, Johannesen J, Kauko L, Kristiansen P, Martikkala M, Martín-Hernández R, Mazur E, Medina-Flores CA, Mutinelli F, Omar EM, Patalano S, Raudmets A, Martin GS, Soroker V, Stahlmann-Brown P, Stevanovic J, Uzunov A, Vejsnaes F, Williams A, Brodschneider R. 2022. Honey Bee Colony Loss Rates in 37 Countries Using the COLOSS Survey for Winter

2019–2020: The Combined Effects of Operation Size, Migration and Queen Replacement. J. Apic. Res. 2022, 1–7.

Hayasaka D, Kobashi K, Hashimoto K. 2019. Community responses of aquatic insects in paddy mesocosms to repeated exposures of the neonicotinoids imidacloprid and dinotefuran. Ecotoxicol Environ Saf. 175: 272-281.

Heinrich BYB. 1981. The mechanisms and energetics of honeybee swarm temperature regulation. J. Exp. Biol. 91, 25–55.

Ilieva I, Ivanova E, Petrov P, Petkov N. 2020. Honey-bee Colony Losses in Bulgaria: A Case Study during the Period 2017-2019. Acta zoologica bulgarica, 15: 117-122.

Ilieva I, Ivanova E, Petrov P, Petkov N. 2021. Losses of Honey Bee Colonies and Risk Factors for their Mortality in Bulgaria during 2020, Ecologia balkanika, Special Edition 4: 173-180.

Ivanova EN, Petrov PP. 2010. Regional differences in honey bee winter losses in Bulgaria during the period 2006-9. Journal of Apicultural Research 49 (1): 102-103.

Ivanova EN. 2018. Population-genetic richness of the Bulgarian honey bee and the history of a 25-year scientific journey, scientific monograph. University Publishing House "Paisii Hilendarski", 314 p.

Malcheva K, Bocheva L, Chervenkov H. 2022. "Spatio-Temporal Variation of Extreme Heat Events in Southeastern Europe". Atmosphere 13(8): 1186.

Matev S. 2020. Annual number of days with precipitation over 1.0 mm in the non-mountainous part of Bulgaria for the period 1961-2018. Conference Proceedings “Climate, atmosphere and water resources in the face of climate change”, Sofia, 15-16 October 2020, 2: 94-101.

Migdal P, Roman A, Popiela-Pleban E, Kowalska-Góralska M, Opalinski S. 2018. The Impact of Selected Pesticides on Honey Bees. Pol J Environ Stud, 27(2): 787-792.

Morawetz L, Köglberger H, Griesbacher A, Derakhshifar I, Crailsheim K, Brodschneider R, Moosbeckhofer R. 2019. Health status of honey bee colonies (Apis mellifera) and disease-related risk factors for colony losses in Austria. PLoS ONE 14, 1–28.

Nikolova N, Ratchev G, Gera M, Krenchev DM, Matev S. 2022. Extreme air temperatures at The south western slope of Pirin Mountain (Bulgaria). l’Acad´emie bulgare des Sciences, Geophysics, Meteorology, 75(1): 71-79.

Ped DA. 1975. On parameters of drought and humidity. Papers of the USSR hydrometeorological center 156: 19–38 (in Russian**).**

Rader R, Reilly J, Bartomeus I, Winfree R. 2013. Native bees buffer the negative impact of climate warming on honey bee pollination of watermelon crops. Glob Chang Biol. 19(10): 3103-3110.

Salmi T, Määttä A, Anttila P, Ruoho-Airola T, Amnell T. 2002. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen’s slope estimates MAKESENS–The excel template application. Finnish Meteorological Institute, Helsinki.

Seitz N, Traynor KS, Steinhauer N, Rennich K, Wilson ME, Ellis JD, Rose R, Tarpy DR, Sagili RR, Caron DM, Delaplane KS, Rangel J, Lee K, Baylis K, Wilkes JT, Skinner JA, Pettis JS, van Engelsdorp D. 2015. Encuesta nacional sobre la pérdida anual de colmenas de abejas manejadas durante 2014–2015 en los EEUU. J. Apic. Res. 54: 292–304

Switanek M, Crailsheim K, Truhetz H, Brodschneider R. 2017. Modelling seasonal effects of temperature and precipitation on honey bee winter mortality in a temperate climate. Sci. Total Environ. 579: 1581–1587.

Tomljanović Z, Cvitković D, Pašić S, Volarević B, Gajger IT. 2020. Production, practices and attitudes of beekeepers in Croatia. Veterinary Arhives, 90(4): 413-427.