Sustainable beekeeping in Visegrad group

Final Report

Brno, 2024

Project: Sustainable beekeeping in Visegrad group

Project no: 22220064

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Report content

1. Project team

University of Veterinary Sciences Brno

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Born on 31th January 1980 in Bratislava. He is specialised on microscopic techniques in the field of food analysis including Melissopalynology. During his career, he has worked on the development of new methods for detecting food adulteration and methods for food quality analysis.

Mgr. Zdeňka Javůrková, Ph.D.
Born on 2th February 1979 in Svitavy. She graduated from the University of Veterinary and Pharmaceutical Sciences in Brno. Since graduating until now, she has been working at the University of Veterinary Sciences in Brno. She is specialised on food microscopy and image analysis, food laboratory management and food quality and safety management.

Mgr. Marie Bartlová, Ph.D.
Born on 15th July 1991 in Třebíč. She has been working at Department of Plant Origin Food Sciences at the University of Veteriany Sciences Brno since 2017. She focuses on the use of microscopic methods in food analysis.

Ing. Simona Ondruchová
Born on 3th September 1990 in Valašské Meziříčí. She worked for several years as a food technologist and product development engineer in various food companies. Currently, she is an assistant at the Faculty of Veterinary Hygiene and Ecology and a Ph.D. student specializing in honey analysis.

University of Chemistry and Technology, Prague

associated professor Ing. Helena Čížková, Ph.D.
Born on 14th September 1973 in Prague. She specializes in identifying causes of sensory defects in food products, predicting shelf life, and developing methods for evaluating food authenticity. She is actively involved in teaching courses Principles of Food Preservation and Food Authenticity and Fraud Detection.

Ing Vojtěch Kružík, Ph.D.
Born on 3th December 1988 in Jihlava. He specializes in food analysis, optimization and development of methods for evaluating food authenticity. Main fields of interest: quality of honey and other bee products, gas chromatography, food chemistry.

Bee Research Institute

Ing. Dalibor Titěra. CSc
Born in Prague on 4th December 1955. Researcher, head of accredited testing laboratory. Reearch interest: Honeybee biology, beekeeping, honeybee genetics, artificial insemination of queenbees; honeybee pathology, control of Paenibacillus larvae and Varroa destructor.

University of Agriculture in Krakow

professor Ing. Józef Hernik, Ph.D.
He is researcher in the Department of Land Management and Landscape Architecture, Faculty of Environmental Engineering and Land Surveying, at the University of Agriculture in Kraków. His main fields of interests and studies are cultural landscapes, land use and environmental development. He specialises in the role of environmental policy, including risk reduction and the role of climate change.

associate professor Ing. Barbara Prus, Ph.D.
Graduated the Faculty of Environmental Engineering and Land Surveying of the Academy of Agriculture in Kraków. She was awarded a PhD in land surveying and cartography, speciality real estate management. Her engineering and technical postdoctoral qualifications in civil engineering and transport, speciality geoinformation systems, land surveying, and spatial engineering.

The University of Veterinary Medicine and Pharmacy in Košice

professor DVM. Slavomír Marcinčák, Ph.D.
Born on 28th March 1975 in Humenné. He is specialised on improving quality of produced foods of animal origin using natural feed additives. During his career, he has worked on the development of new fermented feeds for chickens prepared from cereals by-products by solid state fermentation and filamentous fungi.

associate professor DVM. Dana Marcinčáková, Ph.D.
Born in Košice 27th May 1978. Graduated in field of Food Hygiene in 2002. She is specialised on chemical and biological properties of natural substances, evaluates antioxidant and biological activity of honey, honey bee products and plant extracts.

Semmelweis University, Faculty of Health Sciences

associate professor Csilla Benedek, Ph.D.
Born in Timisoara on 3rd March 1971. She obtained an MSc in chemical engineering in 1994 and obtained a PhD. degree in Chemistry in 2001. Main skills and fields of professional interest: analytical chemistry (especially gas chromatography, spectrophotometry), general food chemistry, food adulteration with honey as the main target, quality management.

Dr. Zsanett Bodor, Ph.D.
Dr. Zsanett Bodor was born 15th August 1993 in Hungary and graduated as dietitian, and nutritionist then obtained a PhD degree in Food Science. Dr. Zsanett Bodor is specialised in honey analysis, especially quality parameters, NIRS and electronic tongue. During her career she was working with the aforementioned methods to check their performance in adulteration detection, origin identification, and revealing overheating.

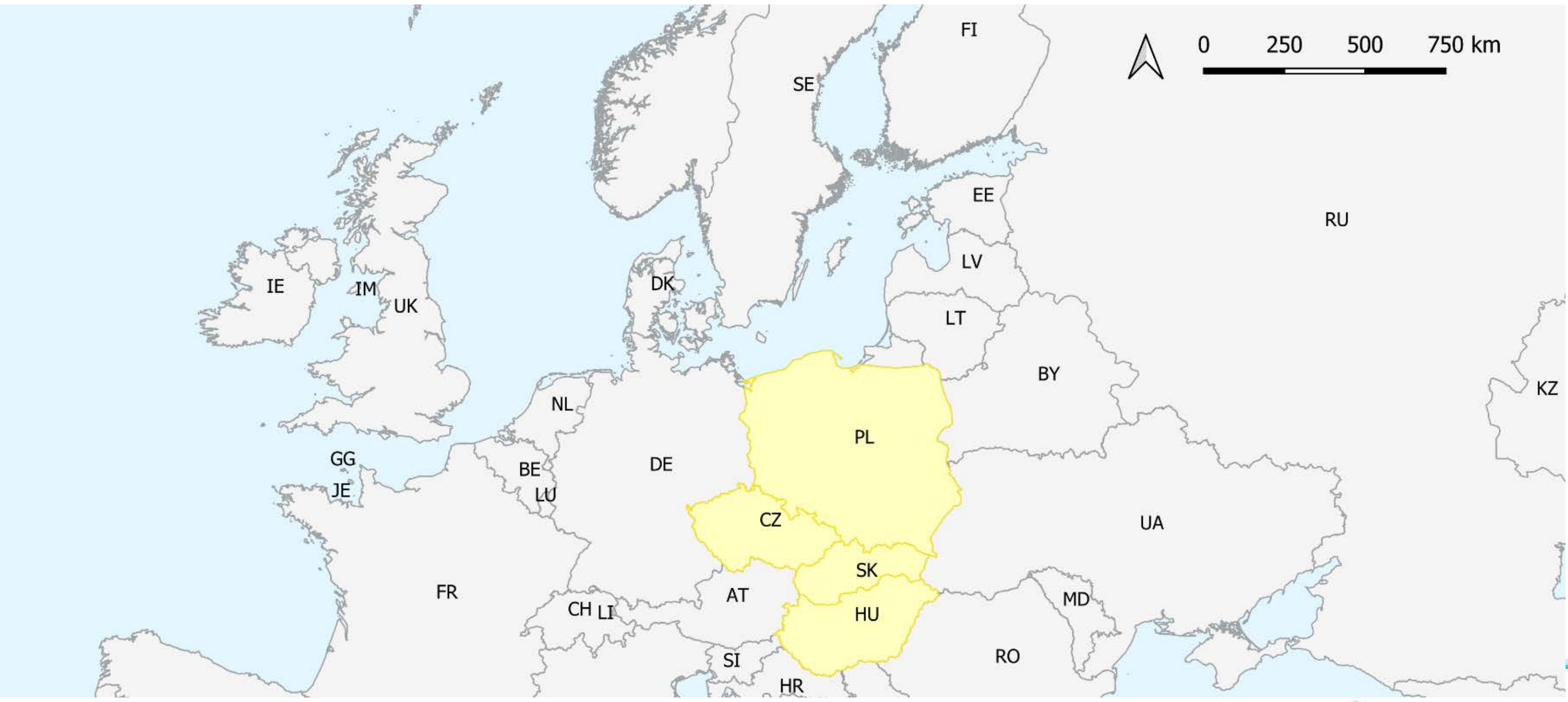
2. Introduction

Beekeeping is an important kind of agricultural production with significant social and environmental impact. Currently, bees face many problems, for example Colony Collapse Disorder (CCD) with unknown etiopathology. The impact of nutrition sources will be monitored by geographic information systems and honey quality evaluation. The knowledge will be shared with national authorities with possibility to set measures to predict optimal hive position to reach sustainable beekeeping in Visegrad Countries (V4G).

One of the hypotheses is nutrition misbalances of bee colony in current ecosystem. For bees feeding not only wild plants are an important source of nutrients, but to much larger extent also plants from intensive agriculture. In all V4G countries the agricultural area is higher than wild country area, which can cause misbalanced bees nutrition and CCD. The impact is given also by anthropogenic land using where some of the localities suffer environmental pollution (mining, extraction), some are highly industrialised, producing pollution sources with different toxicity grades.

Honey quality may be one of indicators to monitor nutrition of bees in V4G countries. Honey is an important source of carbohydrates and source of antioxidants, proteins, and minerals used in bees' nutrition. Modern geographic information systems, able to collect agricultural information from map sources and compare them with honey parameters, can be used for the evaluation of the impact of the current ecosystem to honey quality.

In recent years, geographic information systems have also been used for communication between national authorities and the public. The combination of GIS with analytical information from honey and bee products is a way can help to increase productivity and efficiency of beekeeping practice and ultimately sustainable beekeeping. This project demonstrates the potential of GIS in beekeeping and shows that the combination of GIS and analytical parameters of bee products can predict the potential of hive locations.



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3. Aims

The project combined analytical honey investigation methods with geographical information systems. This unique evaluation shows very precisely the impact of agricultural production on bee nutrition as one of possible factor acting CCD and also shows the effect of soil type on the mineral profile of the honey.

The project compared data sets from semiautomated melissopalynology analysis, spectral analysis, mineral profile analysis and physico-chemical analysis with geographical information systems. The melissopalynology is an important part because pollens are the main sources of proteins which have an important role in honeybee's larvae feeding. In total, 80 honey samples from all over the Visegrad region were used, for some of the scientific interpretation also independently obtained laboratory results were used. More than 720 unique analytical results were obtained in the project. For GIS it was used map sources from:

(1) Vector land cover models from the Copernicus Land Monitoring Service database for the V4 countries were used for the analysis (in shp format) (ISO 19144-2:2012. CORINE Land Cover).

(2) To analyse the quality and agricultural suitability of soils in Poland, vector data obtained from the Provincial Centre for Geodetic and Cartographic Documentation in the form of a soil and agricultural map (shp) was used, presenting the complexes of agricultural suitability of soils, types and subtypes of soils, and the mechanical composition of soils.

(3) To analyse the quality of soil in the Czech Republic, Slovakia and Hungary, data provided by the European Soil Data Centre (ESDAC), esdac.jrc.ec.europa.eu, European Commission, Joint Research Centre in the form of European Soil Database v2.0 (vector and attribute data) using ESDAC Dataset Access (ID: 80476, Figure 1), (Panagos et al. 2012, 2022).


Dataset | References | Submitted Form

European Commission

Joint Research Centre - European Soil Data Centre (ESDAC)

ID	80476
Date - Time	Thu, 07/18/2024 - 15:13
Name of User	Barbara Prus
Organization	University of Agriculture in Krakow
Type of Organization	University
-- Other	
E-mail	b.prus@urk.edu.pl
Purpose	The data will be used for research and educational purposes.

Figure 1: Access to ESDAC Dataset

(4) Vector layers with the spatial locations of apiaries and generated buffers with a radius of 3 km from the location of the apiary were used for the analyses.

(5) Country borders were obtained from the layer CNTR_RG_01M_2020_3035 from https://gisco-services.ec.europa.eu/distribution/v2/countries/countries-2020-files.html .

These systems can be supplemented by automatic systems showing places that are the most suitable for bee feeding. Our project is not aimed to incorporate this system to the national system but to draw attention and show benefit from this implementation and start discussion with national authorities to the innovation and update of current map agricultural systems.

Gathered information and new knowledge was shared with students, national authorities, beekeepers from each country and researchers from around the world.

4. Project output

Beekeepers locality prediction

One of the ways how to predict beehive locality is deep knowledge about nearby vegetation and land usage. In the case that bees are able to fly long distance, around 3-10km, the evaluation of the area is time consuming. During time beekeepers who keep beekeeping practices in the same region, gain good knowledge about richness and usability of the region. For young beekeepers and also in case of the countryside changes the usability of the country can be different. Not only country usability is important for sustainable beekeeping. The other important point is also to produced enough bees products, mainly honey. The quantity as well as quality is important for rentable beekeeping. It is mainly the quality that impacts the financial returns. Considering the climatic and botanical conditions in the Czech Republic, it is not easy to produce monofloral honey with specific quality. There is no honey in the Czech Republic that is protected by any of the international quality marks, nor by a national mark that protect the region of origin of the honey. At the national level, regional delimitation is provided by the national standard "Český med" (the Czech Honey, in Czech), that defines stricter physical and chemical conditions for traditional Czech honey and mainly narrows the origin of honey down to the territory of the Czech Republic. Currently, the consumer can choose of a whole range of kinds and types of honey, which are defined in the Czech Republic in Decree No. 76/2003 Coll. (Czech 2003) which incorporates European Directive No. 110/2001 (Union 2002). In Poland and Slovakia honey are protected also by European quality label (Protected Geographical Indication and Protected Designation of Origin). Hungary and Poland have also national protection where some honey types are included in the list of the Ministry of Agriculture and Rural Development (Organic honey and Honey with Polish agricultural quality mark). Meanwhile, in the European Union (EU) there are 8 honeys with the quality mark of Protected Geographical Indication and 30 with the mark of Protected Designation of Origin.

For identification of the beekeepers predictive ability 336 honeys were evaluated from hobby beekeepers. Data on the botanical origin of honey came from a questionnaire survey and they were compared with melissopalynology and physico-chemical parameters.

The results were described in the study: Pospiech, M., Javůrková, Z., Ljasovská, S., Titěra, D., Čížková, H., Kružík, V., Bartlová, M., Tremlová, B. and Marcinčák, S. BKB23 COMPARISON OF BEEKEEPERS' AND ANALYTICAL DETERMINATIONS OF HONEY ORIGIN. *Journal of microbiology, biotechnology and food sciences*. 13, 6 (2024), e9887. DOI:https://doi.org/10.55251/jmbfs.9887. (Annex 1.)

The statistically significant differences were confirmed between beekeepers' and analytical identification of the honeys. There were differences according to the origin of the honey (blossom, honeydew as well as blended honeys). Overall, results are described in the Figure 2. The results show that combined analytical methods should be used for correct determination of honey origin. The correct determination of honey origin is also important for honey quality protection and is commonly controlled by national authorities. Non-compliance with legislation is also reason for financial penalty from national authorities. On the other hands the results show that there are 23 % more monofloral honey than were declared by the beekeepers. The disagreement in the declaration of monofloral honeys shows that the classification of the origin of honeys is still problematic. Therefore, new methods or a better characterised distinction for monofloral honeys are needed, in conformity with European Committee and the amendment to the Directive 2001/110/ES (Union 2002), respectively directive EU 2024/1438 (Union 2024). On the other hand, further research is needed to identify the environmental, agricultural and behavioural conditions that can lead to the production of monofloral honeys.

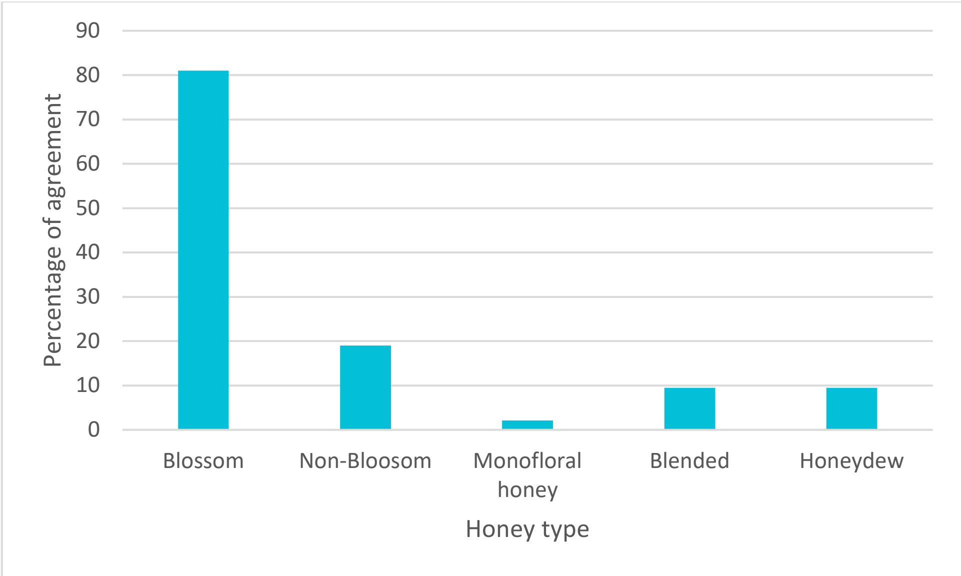
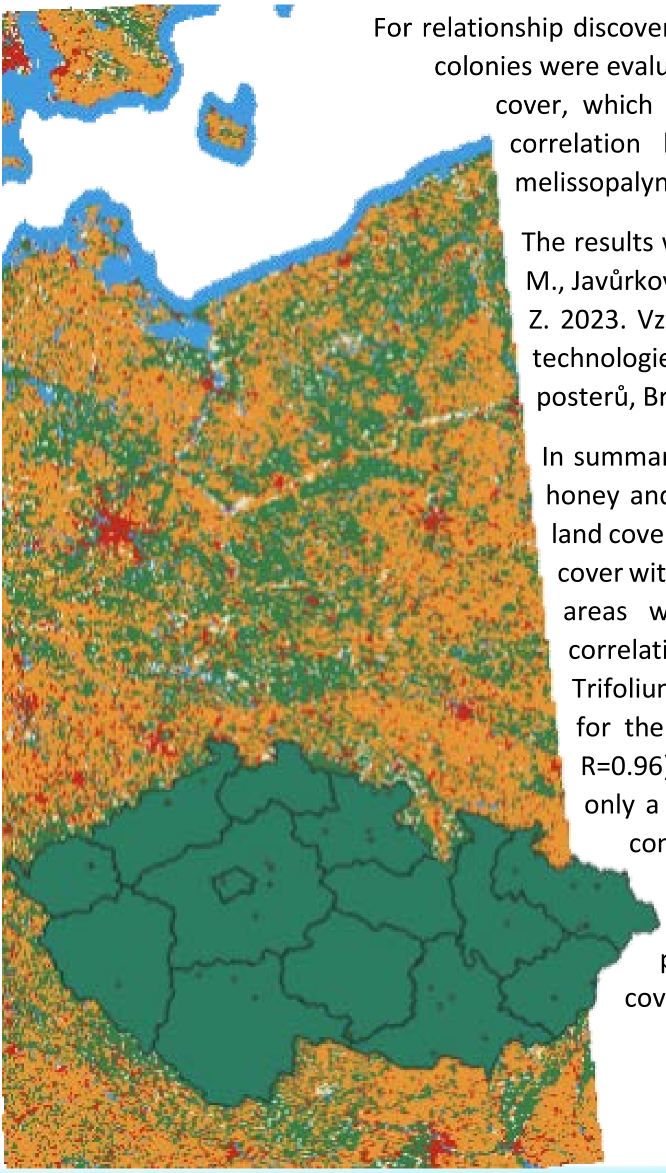


Figure 2: Agreement of beekeepers' declaration on honey origin verified with analytical parameters (%)

Relationship of landscape cover and bee hive population

Remote sensing as part of GIS allows the collection of large amounts of data that can be interpreted in different ways, depending on which satellites and which detectors have been used. European space research provides access to different data. The data are collected as image data, binary data and also in the processed information form. The bee hive locations seem to be connected mainly with land cover. Land cover including information about country side using at in different levels is presented in Table 1. For land cover monitoring, Sentinel-2 satellites are used to image land cover in the visible RGB spectrum (red, green, blue), NIR, near-NIR spectra (Phiri et al. 2020), SWIR and Landsat-8 using VNIR and SWIR (with wavelengths of 443, 865 and 2201 nm) are used (Gorroño et al. 2017). Images satellite data are processed by mathematical models to generate land cover characteristics(Dušek and Popelková 2017), which are freely available as CORINE land cover (CLC).

Honey bee colonies are part of the landscape and their health status, as well as honey production depends on nectar and pollen sources around the habitat of a given colony. Nectar is a source of carbohydrates for the colony, while pollen is a source of protein(Bryś, Skowronek, and Strachecka 2021). Both sources are used in the form of bee products, namely honey and dried pollen. On the other hand, proximity to areas of intensive agricultural activity can be a source of pollution in the form of pesticides, which is one of the causes of CCD (Colony Collapse Disorder) (VanEngelsdorp et al. 2009).



For relationship discovering, 33 hive location and 28,3 km^2 habitat around each bee colonies were evaluated. There were also made comparisons on the level of land cover, which should be used for further studies. Statistically significant correlation between CLC dates and pollen profile determined by melissopalynology analysis was also checked.

The results were described in Czech in the study: Pospiech, M., Bartlová, M., Javůrková, Z., Tremlová, B., Čížková, H., Prus, B., Marcinčák, S., Bodor, Z. 2023. Vztah pokryvu krajiny k pylovému profilu medu. In: Hygiena a technologie potravin LII. Lenfeldovy a Höklovy dny: sborník přednášek a posterů, Brno: Veterinární univerzita Brno, pp. 59 - 66. (Annex 2.)

In summary the relationship between the occurrence of pollen taxa in honey and some types of land cover (Table 1), the European CORINE land cover system, was confirmed. The correlation of pollen taxa of land cover with the proportion of native landscape features and urban green areas was most frequently confirmed. The highest degree of correlation was found for the taxa Aruncus sp., Hipericum sp., Trifolium sp. (R=0.99, R=0.99, R=0.95), for the type 3 classification and for the taxa Brassica sp., Echium sp., Rubus sp. (R=0.99, R=0.96, R=0.96) for the type 2 classification. Type 1 classification confirmed only a weak correlation and is not a suitable classification for this comparison. For this reason we work in further study with more precise classifications as is Type 1. The type 3 classification were commonly used in further study. The correlation patterns are shown in Figure 3 to Figure 14 for specific land cover and all identified pollen taxa.

Table 1: Land cover unit in CORINE land cover system

Code 18	Type 1	Type 2	Type 3
111	Artificial surfaces	Urban fabric	Continuous urban fabric
112			Discontinuous urban fabric
121		Industrial, commercial and transport units	Industrial or commercial units
122			Road and rail networks and associated land
123			Port areas
124			Airports
131		Mine, dump and construction sites	Mineral extraction sites
132			Dump sites
133			Construction sites
141		Artificial, non-agricultural vegetated areas	Green urban areas
142			Sport and leisure facilities
211	Agricultural areas	Arable land	Non-irrigated arable land
212			Permanently irrigated land
213			Rice fields
221		Permanent crops	Vineyards
222			Fruit trees and berry plantations
223			Olive groves
231		Pastures	Pastures
241		Heterogeneous agricultural areas	Annual crops associated with permanent crops
242			Complex cultivation patterns
243			Land principally occupied by agriculture, with significant areas of natural vegetation
244			Agro-forestry areas
311	Forest and seminatural areas	Forests	Broad-leaved forest
312			Coniferous forest
313			Mixed forest
321		Scrub and/or herbaceous vegetation associations	Natural grasslands
322			Moors and heath land
323			Sclerophyllous vegetation
324			Transitional wood land-shrub
331		Open spaces with little or no vegetation	Beaches, dunes, sands
332			Bare rocks
333			Sparsely vegetated areas
334			Burnt areas
335			Glaciers and perpetual snow
411	Wetlands	In land wet lands	Inland marshes
412			Peat bogs
421		Maritime wet lands	Salt marshes
422			Salines
423			Intertidal flats
511	Waterbodies	Inland waters	Water courses
512			Water bodies
521		Marine waters	Coastal lagoons
522			Estuaries
523			Sea and ocean

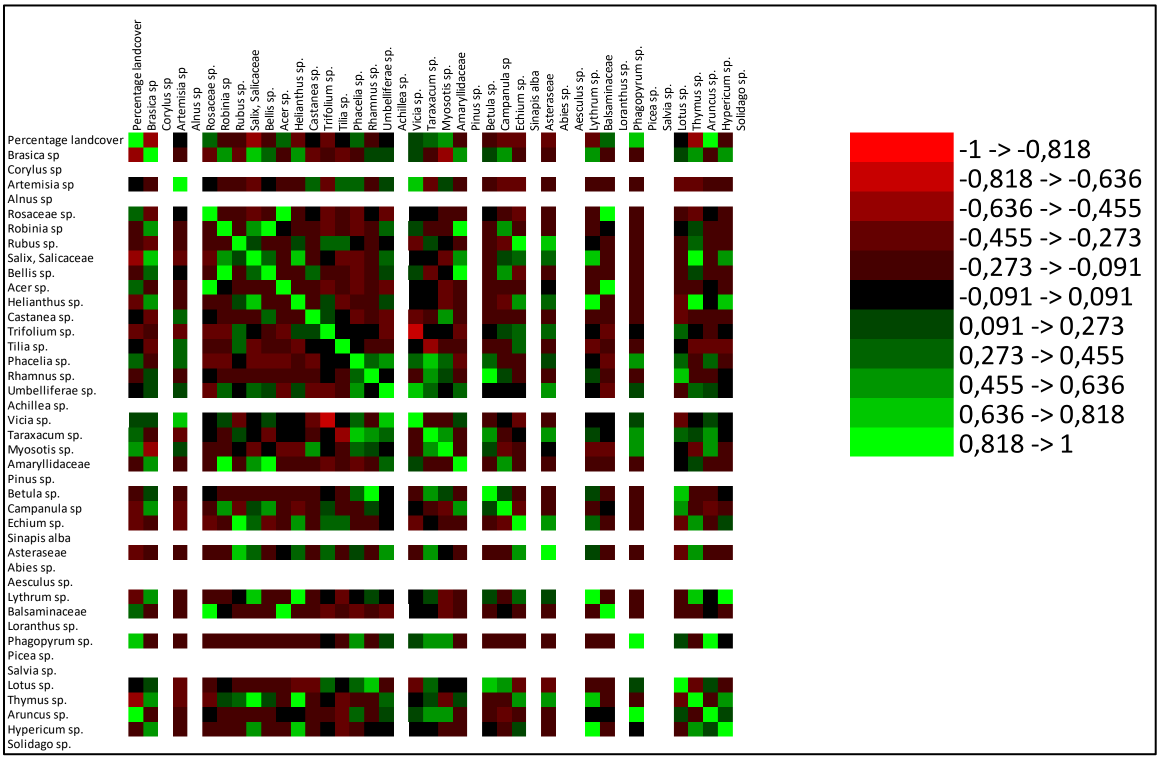


Figure 3: Correlation matrix of botanical taxa for broad-leaved forest.

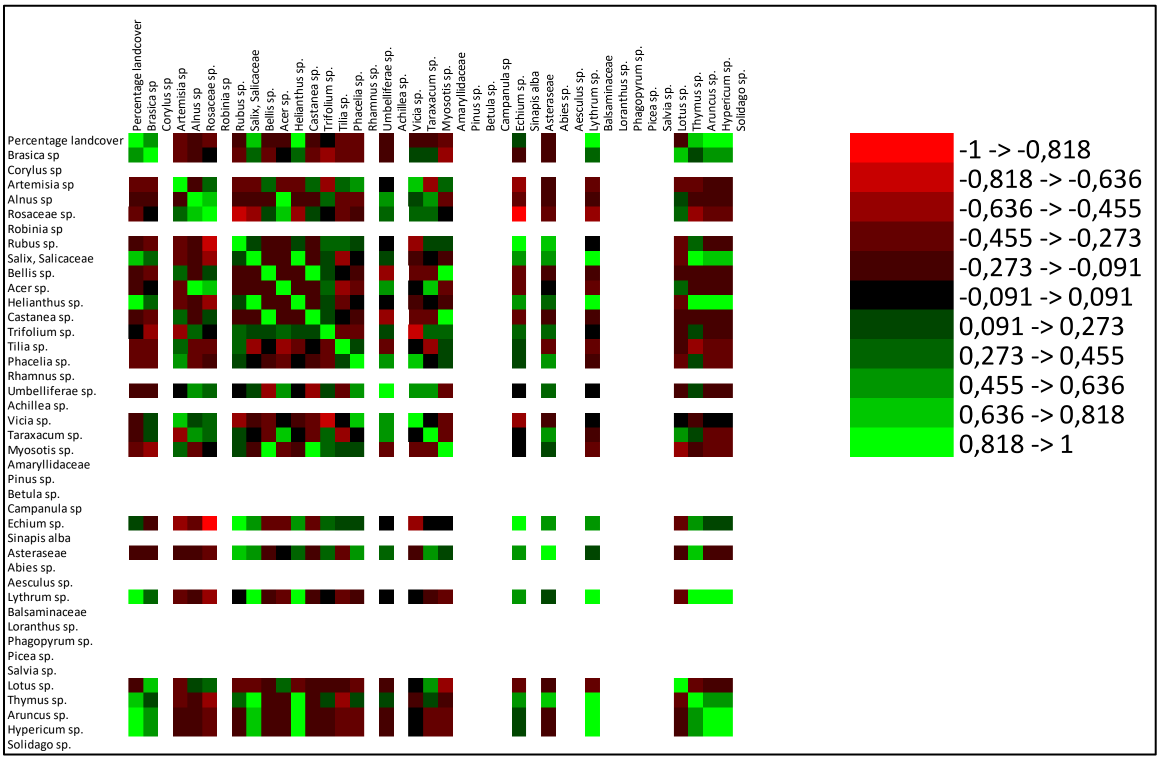


Figure 4: Correlation matrix of botanical taxa for complex cultivation patterns.

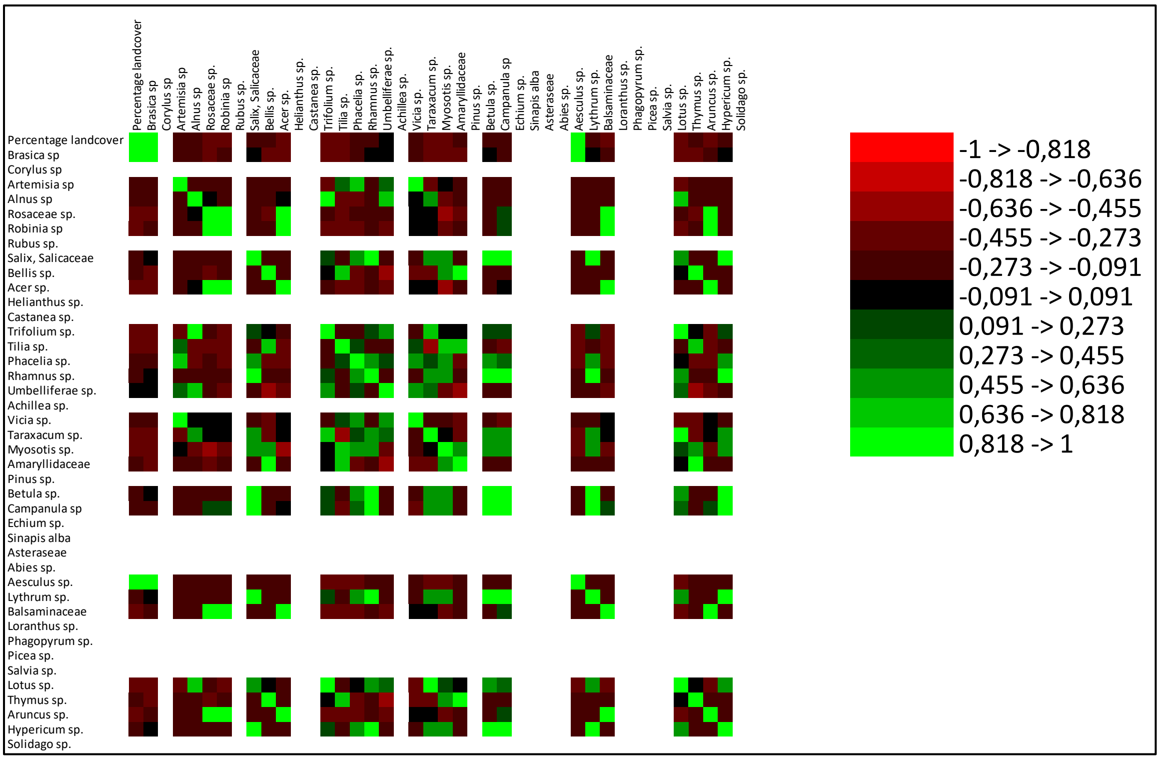


Figure 5: Correlation matrix of botanical taxa for coniferous forest.

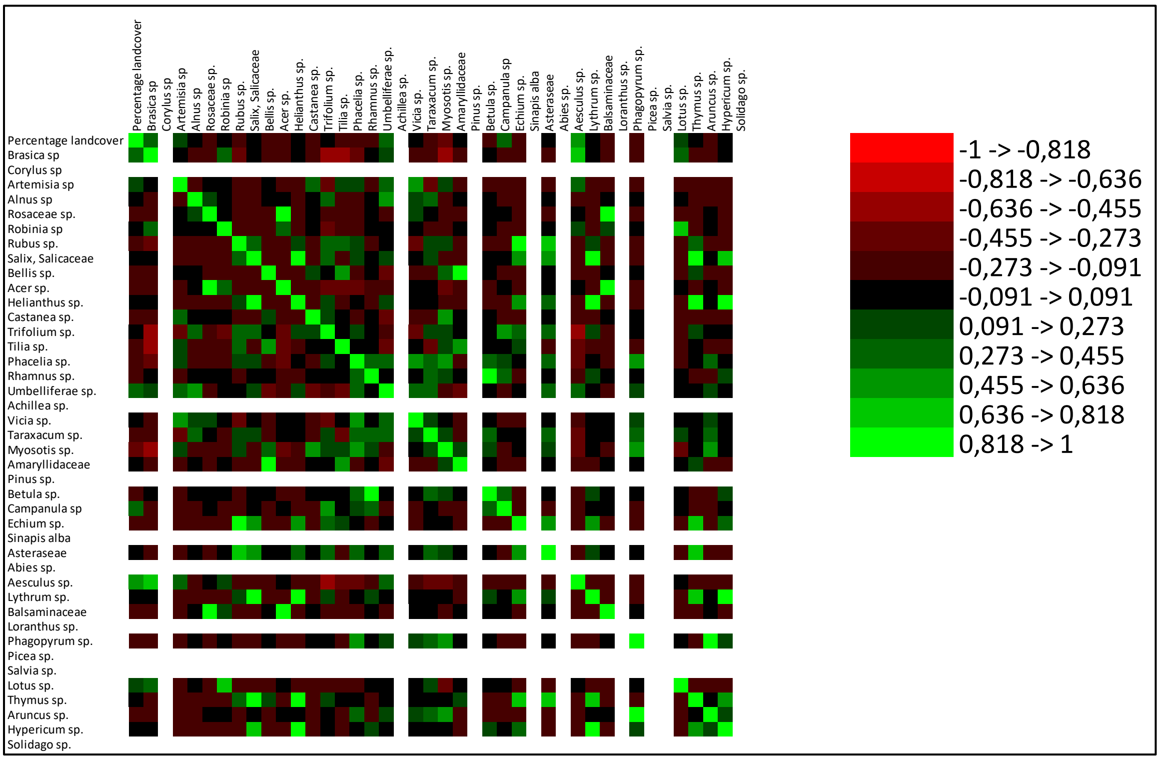


Figure 6: Correlation matrix of botanical taxa for discontinuous urban fabric.

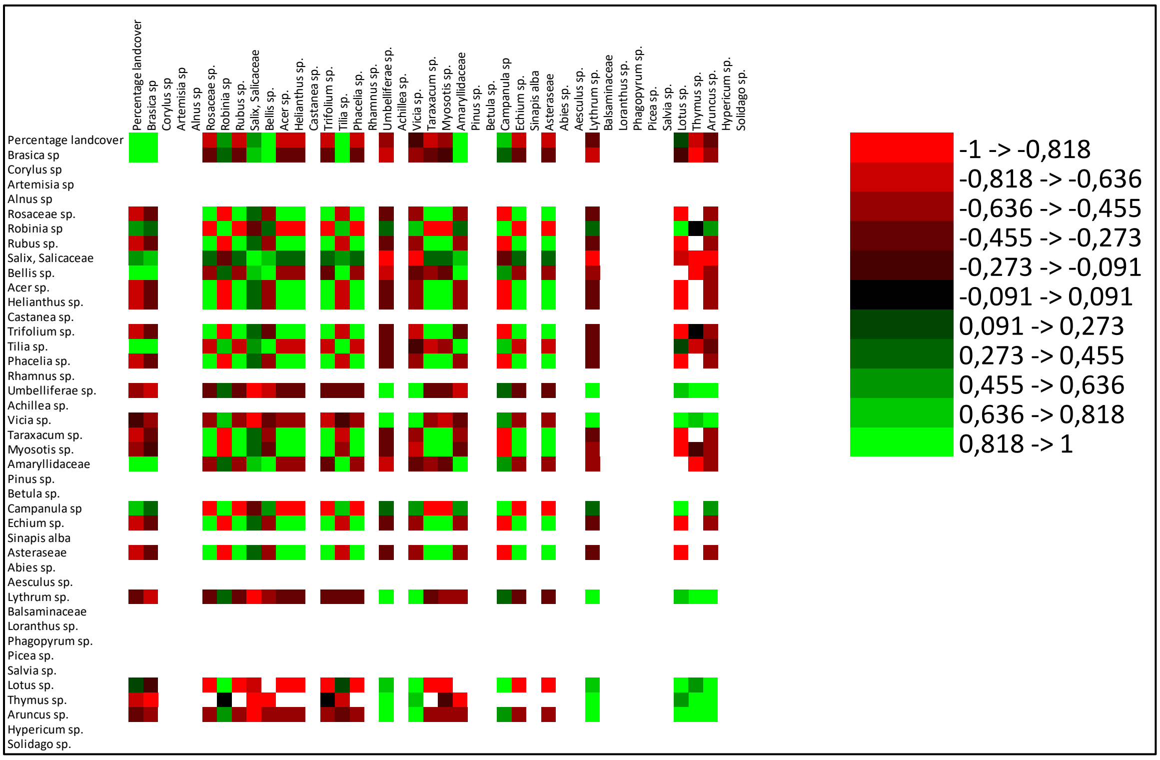


Figure 7: Correlation matrix of botanical taxa for fruit trees and berry plantations.

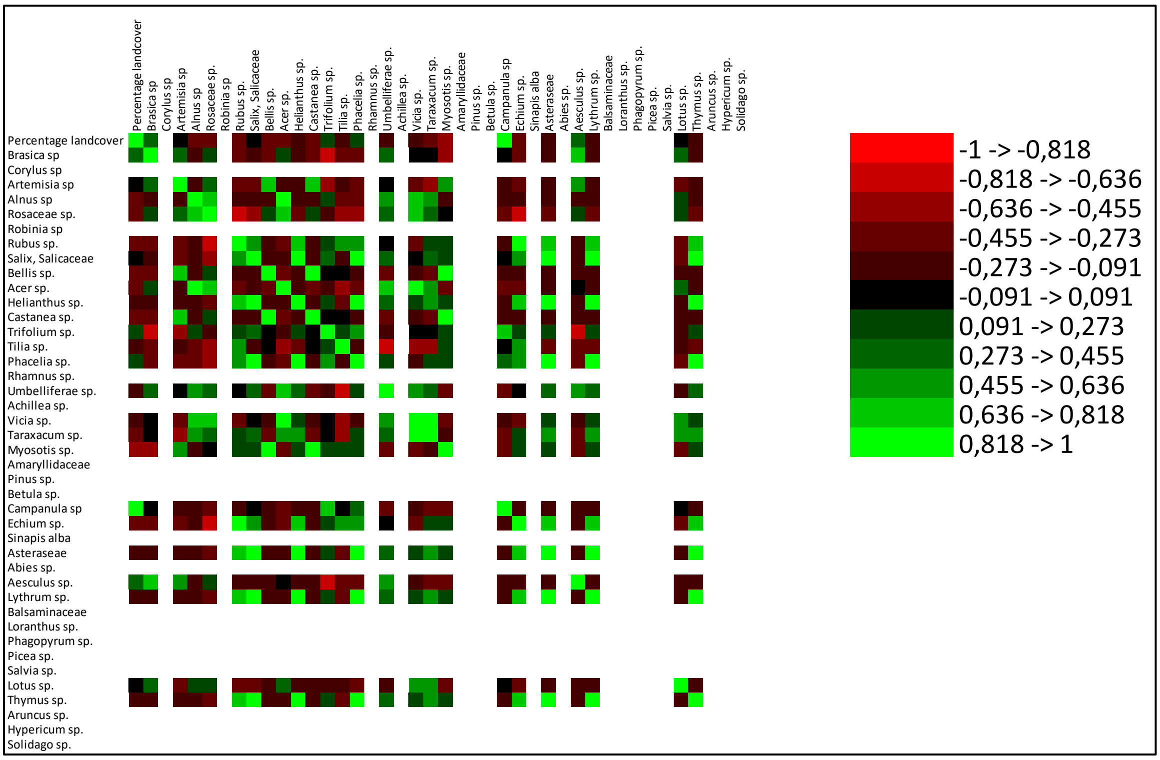


Figure 8: Correlation matrix of botanical taxa for industrial or commercial units.

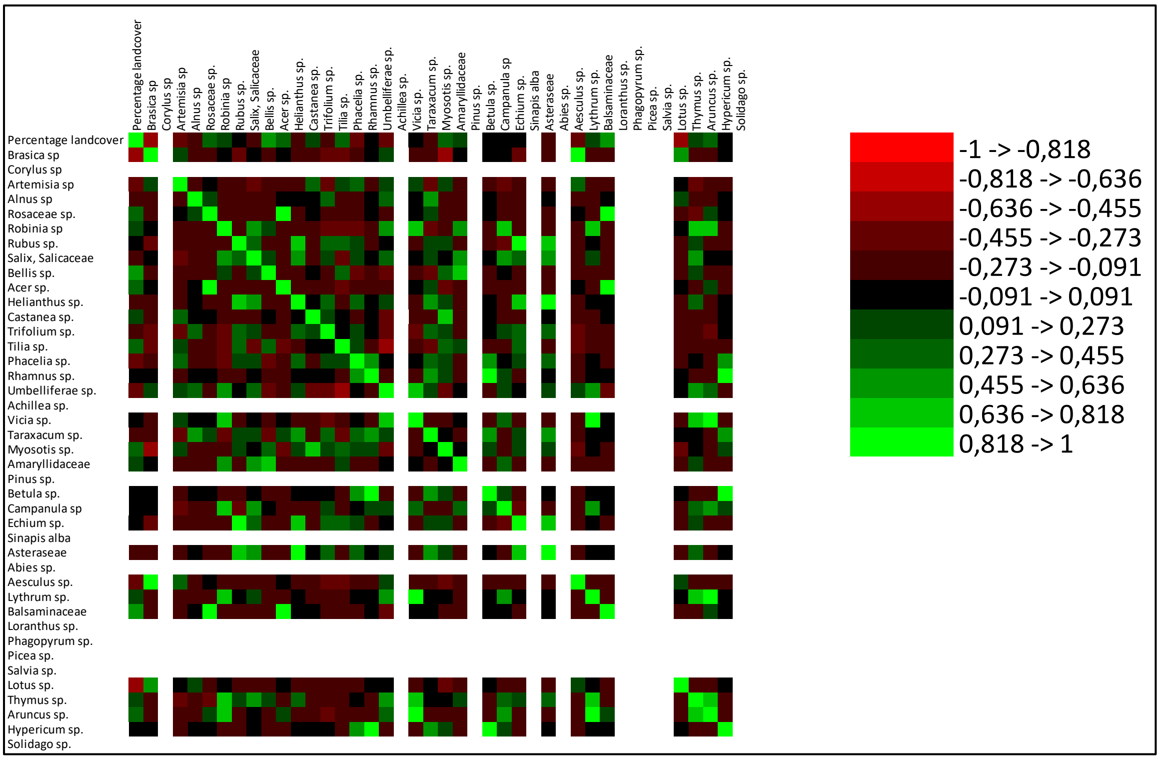


Figure 9: Correlation matrix of botanical taxa for land mainly occupied by agriculture, with significant areas of natural vegetation.

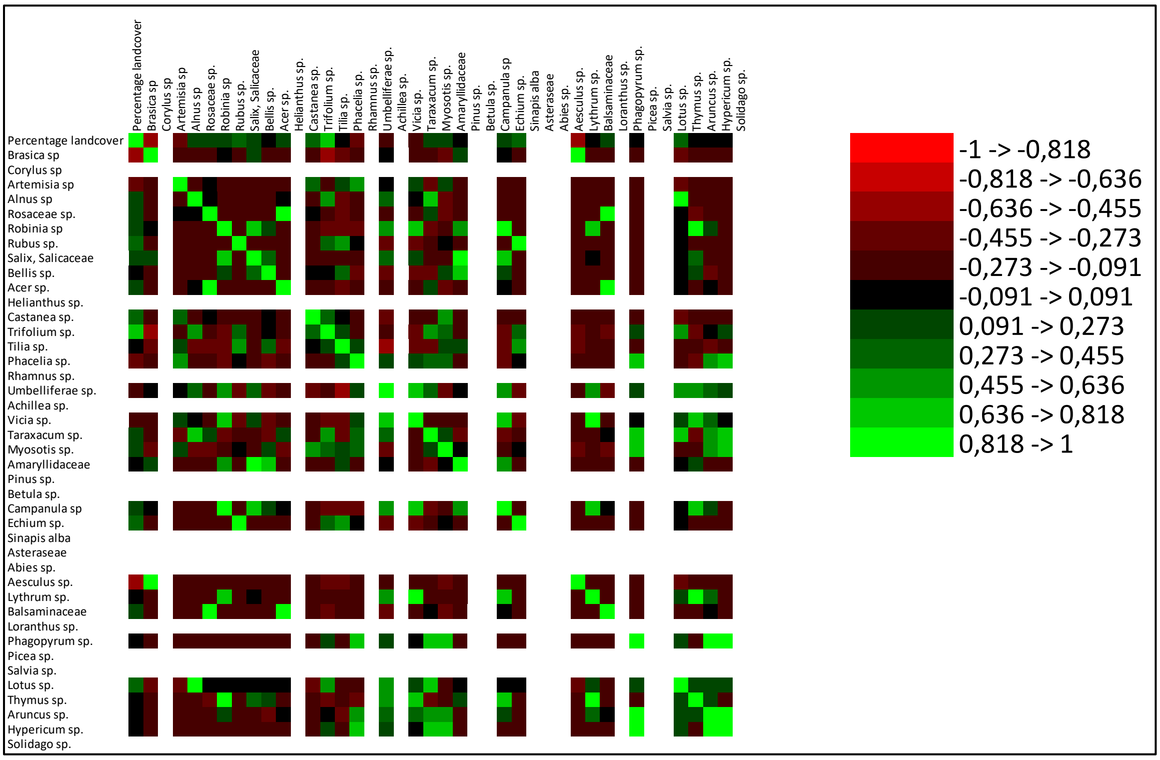


Figure 10: Correlation matrix of botanical taxa for mixed forest.

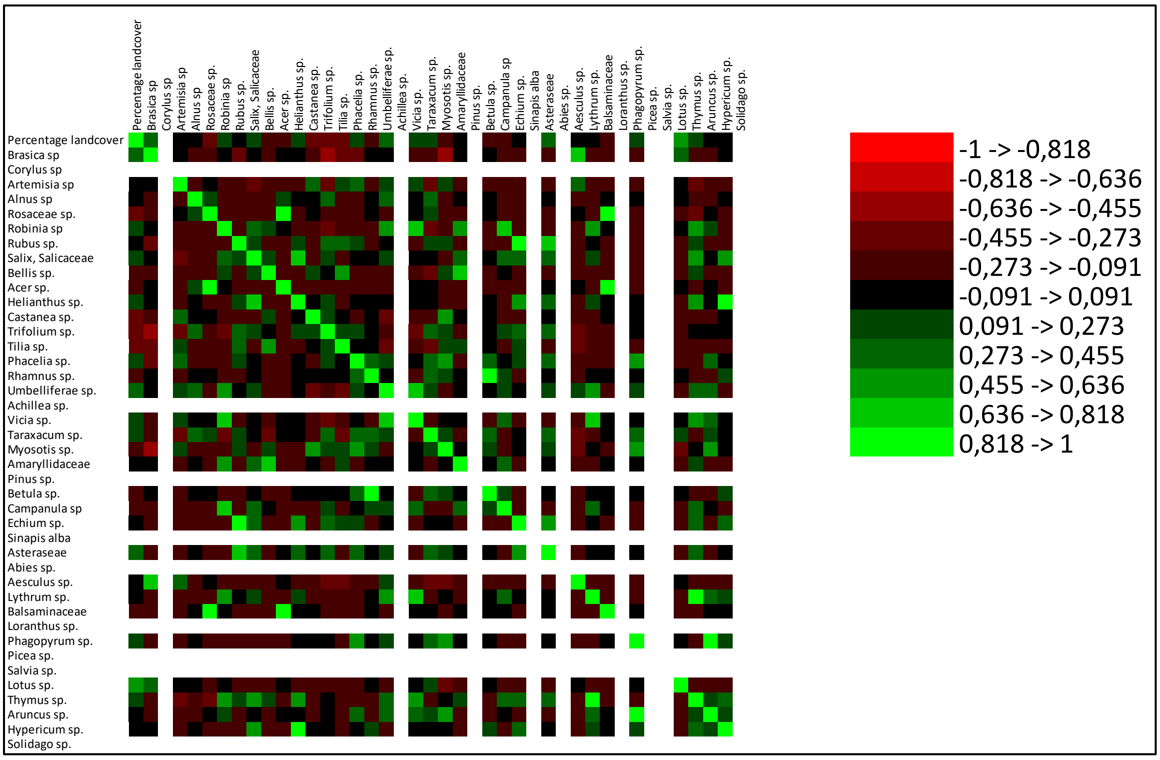


Figure 11: Correlation matrix of botanical taxa for non-irrigated arable land.

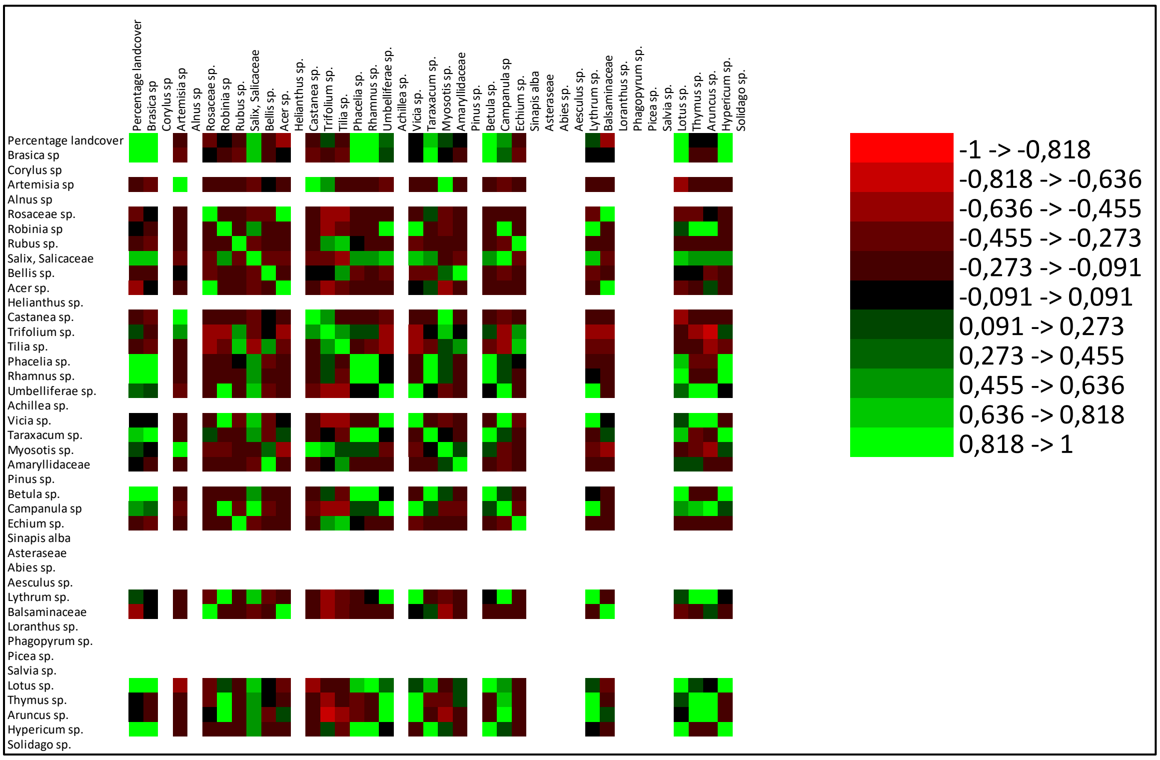


Figure 12: Correlation matrix of botanical taxa for pastures.

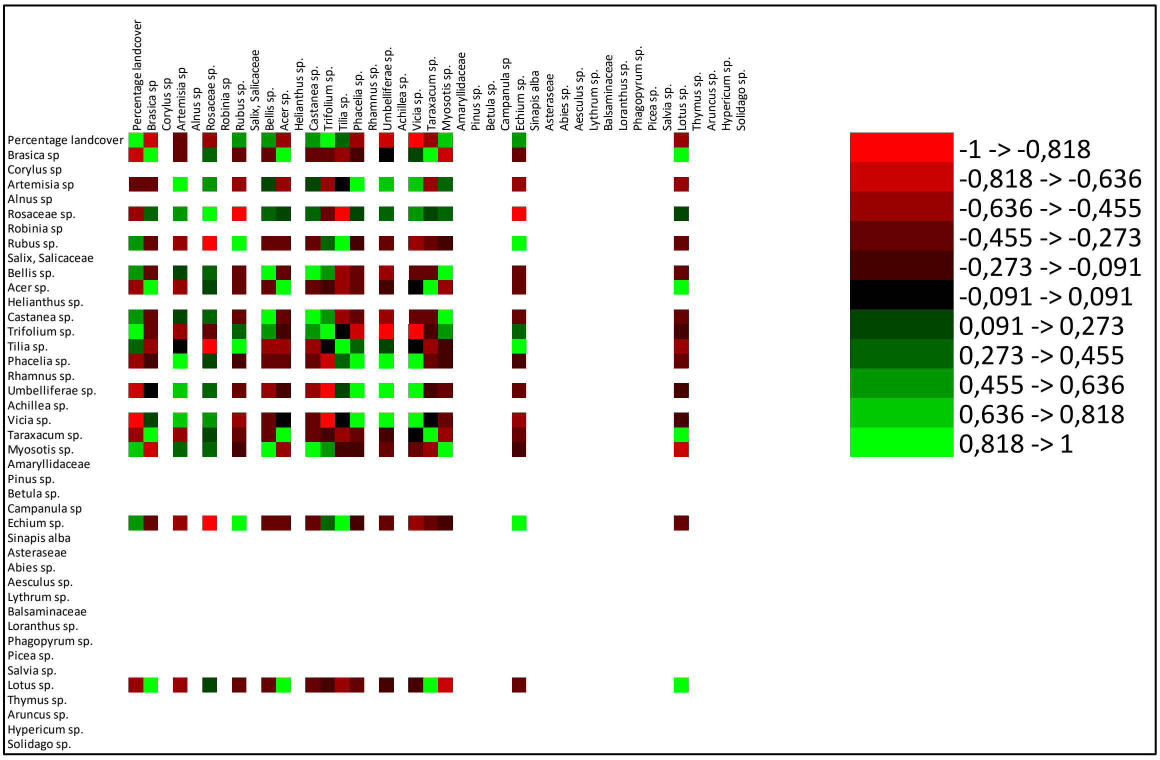


Figure 13: Correlation matrix of botanical taxa for sport and leisure facilities.

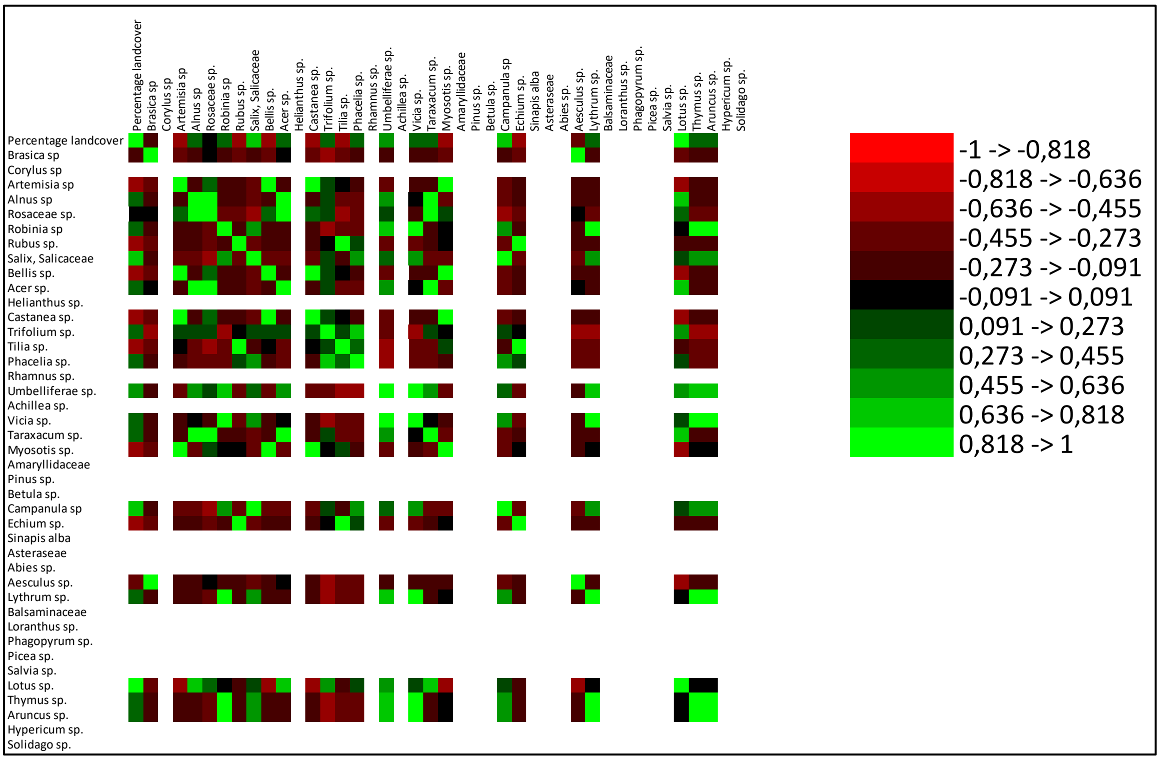


Figure 14: Correlation matrix of botanical taxa for transitional wood land – shrub.

Relationship of landscape cover to the honey parameters

The previous results confirm the impact of the habitat surrounding to bee hive position. The parameters of honey influenced by land cover were evaluated in this project. The impact of bee habitat is known and also used for determination of geographical origin of the honey. The parameters which change the habitat or geographical location are isotope profile of the honey(Kawashima, Suto, and Suto 2018), ^{1}H NMR spectrum (Zheng et al. 2016), or the content of honey components such as minerals, polyphenols or pollen (Karabagias et al. 2014; Ohmenhaeuser et al. 2013; Pasquini et al. 2014). The reason for the numerous methods applied for the geographical identification is the complexity of this identification. Many habitat and environmental factors influenced to the honey characteristic. However, not only the natural country has impact on the bee colony. The anthropogenic factors also have a strong impact. These include, for example, land irrigation, selection of particular botanical species, construction. The human-managed landscape therefore provides a specific source of grazing, but the grazing itself is also influenced by anthropogenic activity. The main aim of this work is to determine the effect of land cover (land use) on the basic composition of honey.

For relationship discovering, 14 different types of land cover were evaluated (Table 2) representing 28,3 km^2 habitat around each bee colony. This data was collected from CLC. The physico-chemical analysis and melissopalynological analysis were performed according to International Honey Committee (IHC) (Bogdanov 2009).

The results were described in Czech in the study: Pospiech, M., Ljasovská, S., Bartlová, M., Čížková, H., Kružík, V., Titěra, D., Prus, B., Tremlová, B. In: *Bezpečnosť a kvalita potravín*, Nitra 2024: Garmond Nitra. Vliv půdního pokryvu na základní parametry medů. 2024, p. 147-151. https://doi.org/10.15414/2024.sqf24-psp (Annex 3.)

In summary, water content, acidity, HMF, diastase activity were not related to land cover. This result is not surprising, as these are parameters that are mainly related to honey processing. Also, diastase activity can be low in some monofloral honeys, on the contrary, HMF content can be high, especially in honeys from tropical areas. Carbohydrates, sucrose, fructose, turanose, maltose, melecitose quantity were without a clear relationship to the land cover. In the case of sucrose, turanose, maltose, and melezitose, this was expected, mainly because the content of these carbohydrates is low and does not vary over the years. On the other hand, differences between land cover for glucose and trehalose are an interesting finding. The highest value of glucose was recorded for sites with coniferous forest (36.01%). For trehalose, the value was statistically highest in the mineral extraction sites (1.11%) and lowest in coniferous forest (0.18%). Melissopalynological analysis determinated high incidence of rape pollen (56%) in areas with coniferous forests. On the other hand, the presence of flowers and dry-loving plants (genera: Helianthus, Echium, Thymus) and willow pollen willow (3.12%) in areas with vine yards is expected. The occurrence of acacia (11.36 %) in areas with fruit trees and berry plantations was also determinated. Willow pollen is typical of spring honeys and more typical of south-eastern regions of Europe, i.e. areas with a warm climate. The prediction of the land cover is show in Figure 15. The linear discrimination analysis was used. The correction coefficient rate (CCR) (Table 3) was only 45%. Further research is needed to confirm or reject the land cover relationship between.

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Table 2: Representative land cover for the bee colonies

Categories	Abbreviation	Frequencies	Area (km^2)	Area (%)
Coniferous forest	Coni	6	73.58	5.45
Complex cultivation patterns	Comp	7	56.76	6.36
Broad-leaved forest	Broa	10	88.45	9.09
Continuous urban fabric	Cont	15	0.89	13.64
Non-irrigated arable land	Non-	17	508.34	15.45
Fruit trees and berry plantations	Frui	3	14.57	2.73
Pastures	Past	6	136.14	5.45
Industrial or commercial units	Indu	7	74.19	6.36
Land principally occupied by agriculture, with significant areas of natural vegetation	Land	19	239.3	17.27
Road and rail networks and associated land	Road	2	15.76	1.82
Mixed forest	Mixe	10	178.41	9.09
Mineral extraction sites	Mine	2	7	1.82
Vine yards	Vine	2	14.63	1.82
Sport and leisure facilities	Spor	4	14.1	3.64

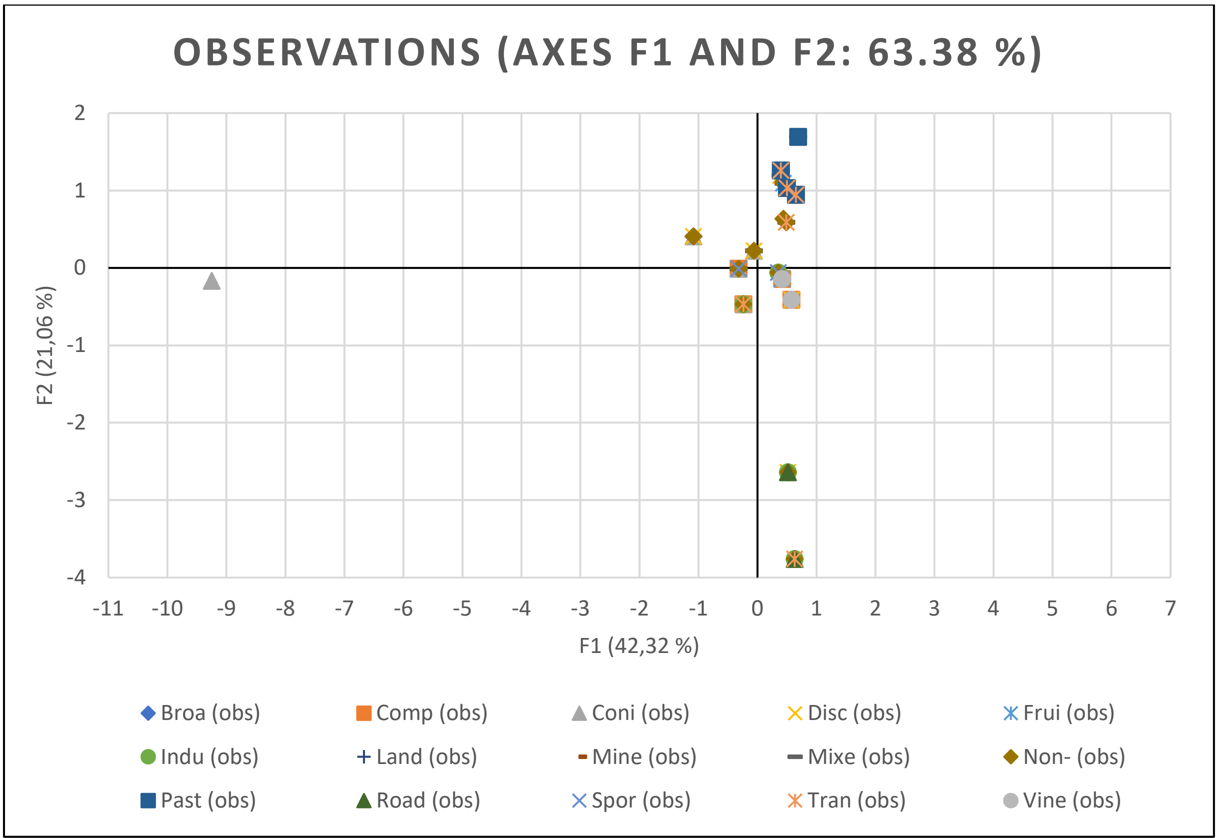

Figure 15: Plot of linear discrimination analysis for land cover.

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Table 3: Confusion matrix of the training samples for land cover

from \ to*	Broa	Comp	Coni	Disc	Frui	Indu	Land	Mine	Mixe	Non-	Past	Road	Spor	Tran	Vine	Total	CCR %
Broa	53	0	0	0	1	0	14	8	0	0	0	0	0	0	0	76	69.74%
Comp	0	33	0	0	0	0	4	4	0	10	0	0	0	0	0	51	64.71%
Coni	0	0	48	0	0	0	12	0	0	13	0	0	0	0	0	73	65.75%
Disc	15	19	0	53	0	42	24	4	0	56	0	0	0	0	0	213	24.88%
Frui	0	0	0	0	10	0	0	0	0	1	3	0	0	0	0	14	71.43%
Indu	0	0	0	20	0	38	2	2	0	12	0	0	0	0	0	74	51.35%
Land	0	0	0	13	21	5	78	28	0	30	25	0	0	0	0	200	39.00%
Mine	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	8	50.00%
Mixe	41	0	0	0	21	0	39	0	0	13	0	0	0	0	0	114	0.00%
Non-	45	38	0	7	46	0	30	3	0	313	26	0	0	0	0	508	61.61%
Past	9	0	0	0	0	0	17	17	0	0	25	0	0	0	0	68	36.76%
Road	0	0	0	5	0	10	0	0	0	0	0	0	0	0	0	15	0.00%
Spor	0	0	0	0	0	0	5	5	0	4	0	0	0	0	0	14	0.00%
Tran	0	0	0	0	0	5	0	0	0	5	4	0	0	0	0	14	0.00%
Vine	0	11	0	0	0	0	0	0	0	4	0	0	0	0	0	15	0.00%
Total	**163**	**101**	**48**	**98**	**99**	**100**	**229**	**75**	**0**	**461**	**83**	**0**	**0**	**0**	**0**	**1457**	**44.96%**

*abbreviations are explained in Table 2

Relationship between soil type and honey parameters

The geographical origin of honey is related not only to the botanical taxa characteristic of the area, but also by the type of soil where are plans grooving. In the case that honey should be produced without direct human influence on its composition the mineral content of honey reflected the soil and plants in the habitat of bee colony. For this reason, the mineral profile of honeys is used to demonstrate the geographical origin of the honey (Chudzinska a Baralkiewicz 2010).

World wilde scientist describe the possibility of classifying of the honeys according to their mineral content. For this different trace elements are used (Solayman et al. 2016). Cd, Pb, Fe, Mn, Cu, Ni, Cr, Zn, Al and Se were determined in a Turkish study (Tuzen et al. 2007), Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Sr, Th, Tl, U and Zn were determined in an Italian study (Pisani, Protano, and Riccobono 2008), Co, Cu, F, Fe, I, Mn, Ni, Sr, Zn, Cl, Na, K, Mg, Cd and Pb were determined in Egypt (Rashed and Soltan 2004).

For discovering relationship between honey and the analytical parameters of soil 31 samples of honey were evaluated. For soils the organic carbon content (%), humus (%), $CaCO_3$, pH activity (H_2O), pH exchange (KCl), titration activity (mval/100 g), H^{+1}, contents of exchange bases (S, mval/100g), maximum sorption capacity (T, mval/100g), degree of sorption saturation (V %, P_2O_5 and K_2O) were used for evaluation. Soil profile characteristics were taken from a systematic soil survey (Comprehensive Soil Survey) from Czech national database (Czech 2024). Data obtained from probes within the range of the sites (3 km) from which honey samples were obtained were used for the evaluation.

The results were described in Czech in the study: Javůrková, Z., Štarha, P., Schmidlová, S., Tremlová, B., Pospiech, M., Bartlová, M. Vliv minerálního složení půdy na vlastnosti medu. In: *Hygiena Alimentorum XLIV*, Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach, 2024, pp. 351-354. ISBN 978 80 8077 822 4. (Annex 4.)

In summary, a strong correlation was confirmed between the minerals Mg, Ni, Cu, Cd, As contained in honey and organic carbon, humus and titration acidity (*Figure 16*). The correlation was further confirmed between Mn, K in honey and organic carbon, soil humus and acidity. The correlation between Ca in honey and $CaCO_3$ was not confirmed, nor was the correlation between K in honey and K_2O in soil. This may be due to the input of these elements into the soil by human activity, which is dependent on the crops grown and their mineral requirements and is changed during the years. Therefore, minerals that are not classified as essential plant nutrients and therefore not used as fertilisers have a more significant influence on the determination of the geographical origin of honey than minerals commonly used as fertilisers. So for predictive mechanism correlation between organic carbon, humus and titration acidity the Ni, Cu, Cd, As is most relevant. The predictivity power is also documented in *Figure 17* where 4 clusters in 95% probability was confirmed. The samples S20 and S24 were different in comparison with other samples and rest of the samples form two clusters. The further research is possible, but it needs laboratory analysis of the soil, so it is not usable for GIS systems and automatic predictive mechanism.

Visegrad Fund

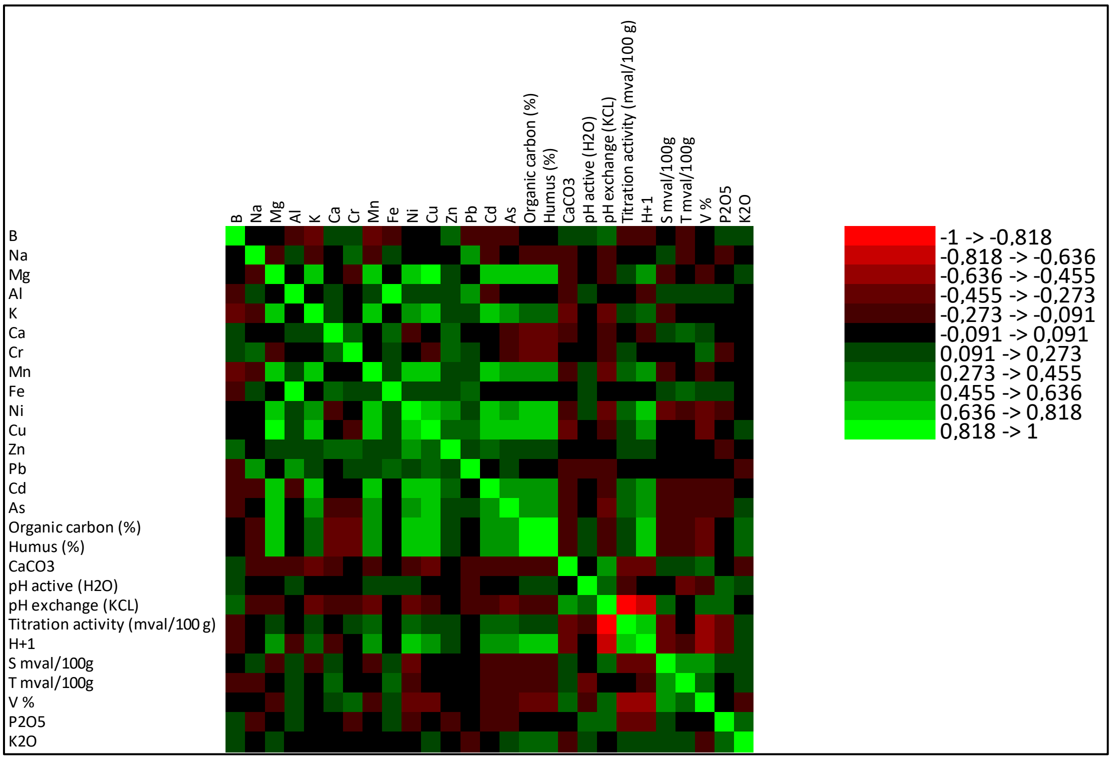


Figure 16: Correlation matrix of soil analytical parameters.

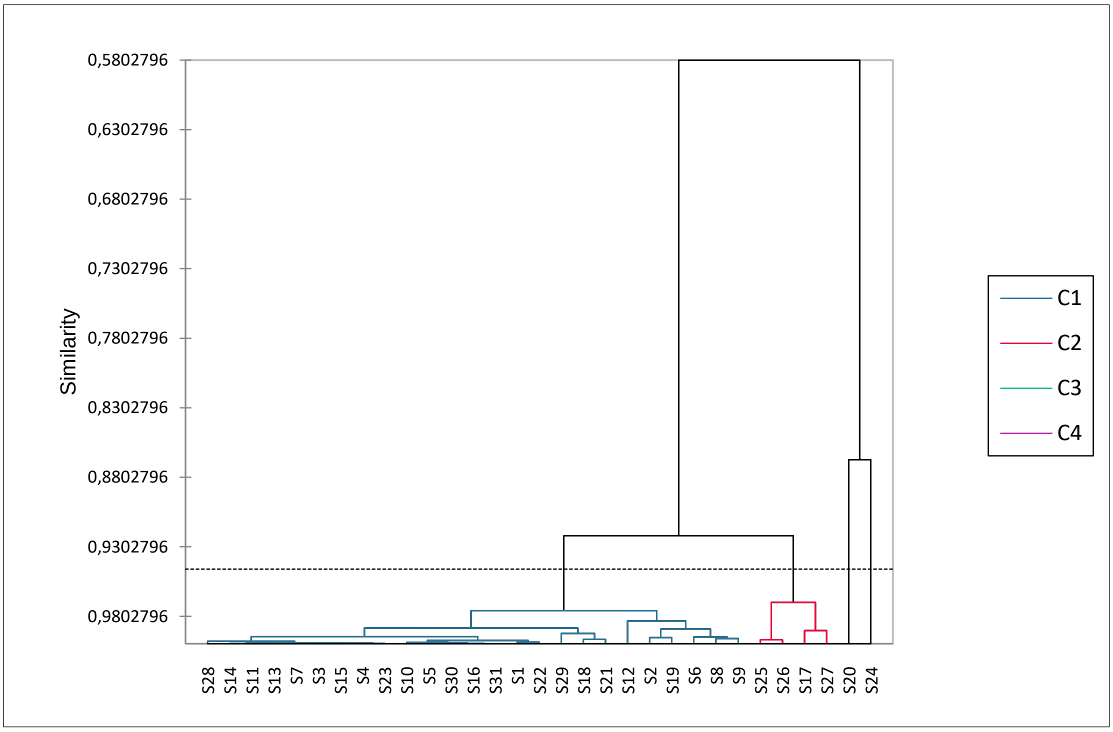


Figure 17: Agglomerative hierarchical clustering dendogram based on analytical parameters of soil.

Bee hive differences from one locality corresponding with one habitat

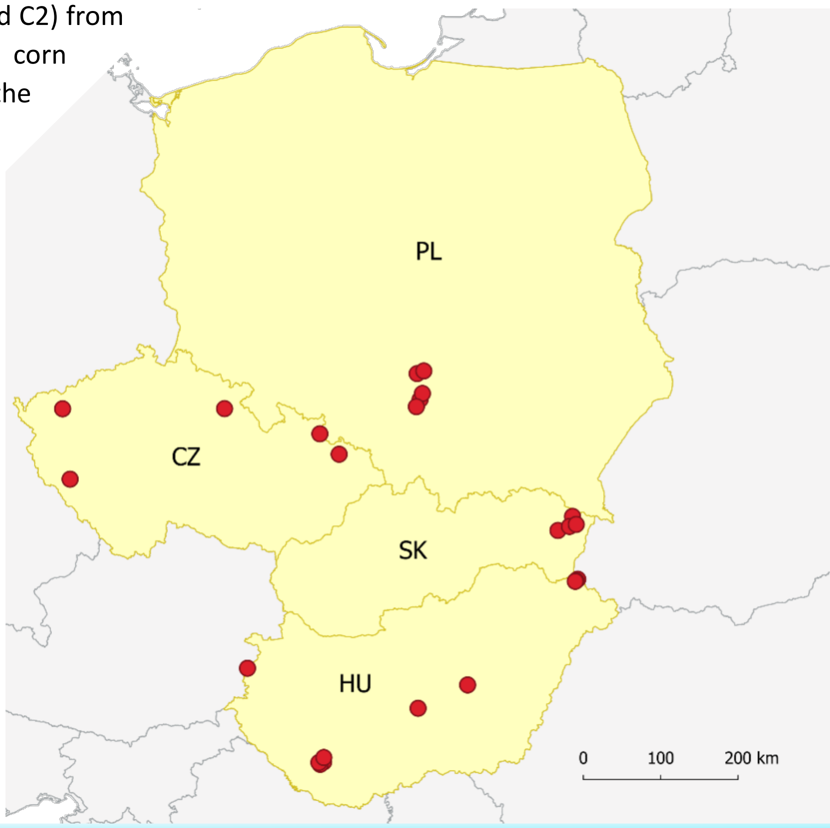
Not only habitat has impact to the honey bee colony. It is also known, that bee colony have different preferences in collected nectar, pollen (Khan and Ghramh 2021), water source and flying distance. In general speaking the physico-chemical parameters of honey are influenced by several factors. In particular, water content is related to the degree of maturity of honey, honey processing and, in rare cases, climatic conditions (Manickavasagam, Saaid, and Osman 2022; Uran, Aksu, and Dülger Altiner 2017). The acidity of honey is determined by the organic acid content. This parameter increases in time, but also with the fermentation of honey, where yeasts ferment sugars to organic acids. Among the chemical parameters, carbohydrates also characterise the site, since the nectar of the plants has different glucose and fructose contents. However, the content of other carbohydrates such as trehalose, maltose, raffinose, etc. can also be observed (Machado De-Melo et al. 2018). The colour is influenced by the content of phenolic substances dissolved in the honey. The colour is also influenced by the amount of pollen and last but not least by the mineral content, the amount of carbohydrate crystals and the water content.

For discovering differences in bee colonies in one the localities were used 60 honey samples. Physico-chemical parameters (water content, conductivity, and fructose, glucose, sucrose, turanose, maltose, trehalose, melibiose, and melezitose content) and colour parameters (CIE Lab) were analysed.

The results were partially published in Czech in the study: Bartlová, M., Marcinčáková, D., Kružík, V., Čížková, H., Bodor, Z., Benedek, C., Tremlová, B., Pospiech, M., Javůrková, Z. Rozdíly fyzikálně chemických parametrů medů z více úlů jedné lokality. KONFERENCE HYGIENA ALIMENTORUM XLIV. Štrbské Pleso, Slovenská republika, 2024. (Annex 5.)

In summary, in this work was confirmed that individual bee colonies produce honey with different physico-chemical composition and colour characteristics, which is in accordance with the beekeepers' claims. In Slovakia the highest results agreement was 43 % for light flower honey from the Stakčín. The lowest agreement was 25 % for dark flower honey from the Belá nad Cirochou. In Poland the highes agreement was 36 % for solidago honey (C1 and C2) from the Łazy, the lowest agreement was 7 % for corn flower honey from Kuśmierki. In Hungary the highest agreement was 36 % for bastard indigo and chestnut honeys (C1 and C4) from the Tiszaszentmárton and Velem, the lowest agreement was 29%, surprisingly across all regions and most honey types Table 4.

The differences in the agreement of the results could be due not only to different preferences of the bee community, but also to different stages of colony development during honey-laying, which is multifactorially influenced by a number of factors ranging from diseases to beekeeping practices.



Visegrad Fund

Table 4: Percent agreement of physico-chemical parameters of honey from Poland and Hungary

Poland

Zawiercie

Zawiercie	C 1	C 2	C 3	C 4
C 1		0.29	0.29	0.29
C 2	0.29		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

Podlesice

Podlesice	C 1	C 2	C 3	C 4
C 1		0.29	0.29	0.29
C 2	0.29		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

Łazy

Łazy	C 1	C 2	C 3	C 4
C 1		0.36	0.21	0.21
C 2	0.36		0.21	0.21
C 3	0.21	0.21		0.36
C 4	0.21	0.21	0.36	

Kuśmierki

Kuśmierki	C 1	C 2	C 3	C 4
C 1		0.07	0.07	0.07
C 2	0.07		0.07	0.07
C 3	0.07	0.07		0.07
C 4	0.07	0.07	0.07	

Rogaczew

Rogaczew	C 1	C 2	C 3	C 4
C 1		0.14	0.14	0.14
C 2	0.14		0.14	0.21
C 3	0.14	0.14		0.14
C 4	0.14	0.21	0.14	

Hungary

Bács Kerekegyháza

Bács Kerekegyháza	C 1	C 2	C 3	C 4
C 1		0.29	0.29	0.29
C 2	0.29		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

Szolnok

Szolnok	C 1	C 2	C 3	C 4
C 1		0.36	0.29	0.29
C 2	0.36		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

Tiszaszentmárton

Tiszaszentmárto	C 1	C 2	C 3	C 4
C 1		0.36	0.29	0.29
C 2	0.36		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

Velem

Velem	C 1	C 2	C 3	C 4
C 1		0.29	0.29	0.29
C 2	0.29		0.29	0.29
C 3	0.29	0.29		0.36
C 4	0.29	0.29	0.36	

Kaposvár

Kaposvár	C 1	C 2	C 3	C 4
C 1		0.29	0.29	0.29
C 2	0.29		0.29	0.29
C 3	0.29	0.29		0.29
C 4	0.29	0.29	0.29	

* green: more agreement, yellow: less agreement

Impact of the region on the honey parameters

The region has a strong influence on the bee colony and the bee products. It is also known that the regional label or quality standard is one of the important points for sustainable beekeeping. The main reason for this is that beekeepers can sell regional honey with higher added value. Higher profits allow beekeepers to invest more in veterinary care, breeding practices and generally better care for their colonies. In our research, we confirmed the worldwide knowledge about regional determination of honey by multivariate statistical methods for different parameters and show that these models work also for honey in the Visegrad Four countries. The advantage is also that the designation of a honey region also prevents the adulteration of honey and the import of honey from abroad. All these issues are important for sustainable beekeeping in the Visegrad region.

To evaluate the regional impact of different Visegrad countries on honey parameters, 80 honeys were evaluated, 20 from each participating country. Physico-chemical parameters (water content, conductivity and fructose, glucose, sucrose, turanose, maltose, trehalose, melibiose and melezitose content), colour analysis (CIE Lab), trace element analysis (B, Na, Mg, Al, Ca, K, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Cd, As) and melissopalynological analysis were carried out.

The results were partially published in the studies: Benedek. C., Marcinčáková, D., Marcinčák S., Pospiech, M., Prus, B., Hemik, J., Bodor, Z. Application colour measurements in honey authentication - a case study. In: Apidologická konferencia BeeConnected 2024, Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach, 2024, pp 3. ISBN 978-80-8077-819-4. (Annex 6.)

Marcinčáková, D., Marcinčák S., Pospiech, M., Prus, B., Bodor, Z. Určenie krajiny pôvodu na základe minerálneho profilu medu. In: Apidologická konferencia BeeConnected 2024, Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach, 2024, pp 18. ISBN 978-80-8077-819-4. (Annex 7.)

Kružík, V., Čížková, H., Pospiech, M., Titěra, D., Hernik, J., Benedek, C. Kvalita a autenticita medu v zemích visegrádské čtyřky. In: Apidologická konferencia BeeConnected 2024, Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach, 2024, pp 18. ISBN 978-80-8077-819-4. (Annex 8.)

In summary, this work confirmed differences between honey parameters in the four Visegrad countries. Also, in our research we first characterised honey differences in term of physico-chemical and melissopalynological parameters. The characterisation of Visegrad honey is important for the protection of the designation of origin and for sustainable apiculture. The multivariate analysis for physico-chemical parameters (Figure 18), mineral profile (Figure 19), colour (Figure 20) and melissopalynology (Figure 21) demonstrate the potential of these methods in regional differentiation. The agreement rate was 89% for physico-chemical, 86.5% for mineral profile, 66.2% for colour and 100% melissopalynology. The results show the differences between analytical parameters and agreement. The highest agreement with melissopalynology analysis is not surprising because in each country there are different sources of nectar and pollen. The highest similarity is found in Slovakia and Poland (Figure 21), where the climate of the sampling habitat is most similar.

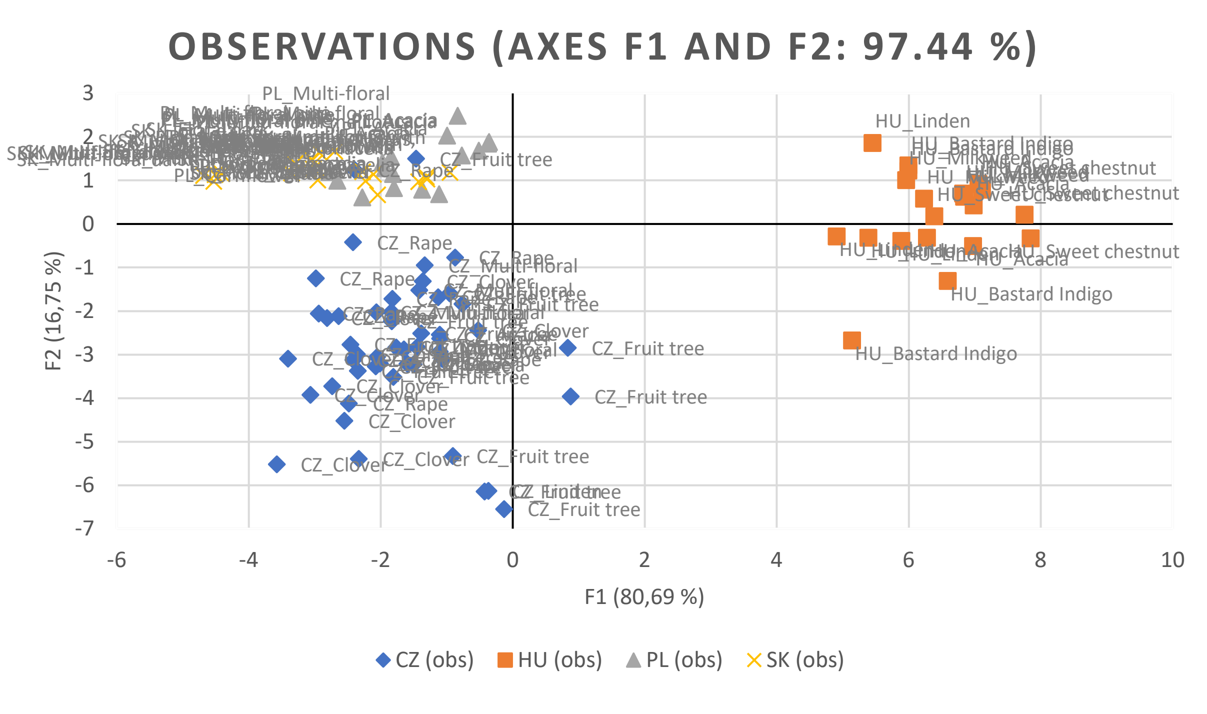


Figure 18: Plot of linear discrimination analysis for physico-chemical parameters.

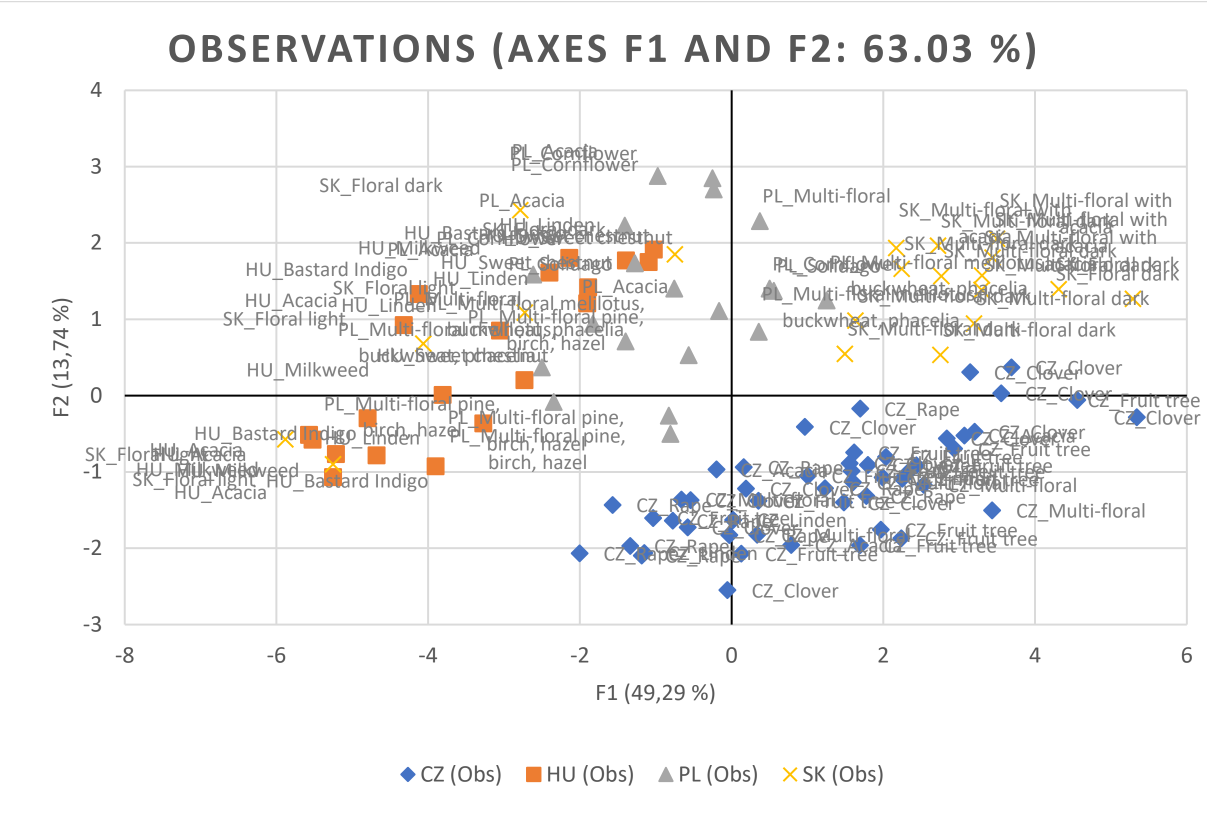


Figure 19: Plot of linear discrimination analysis for mineral profile.

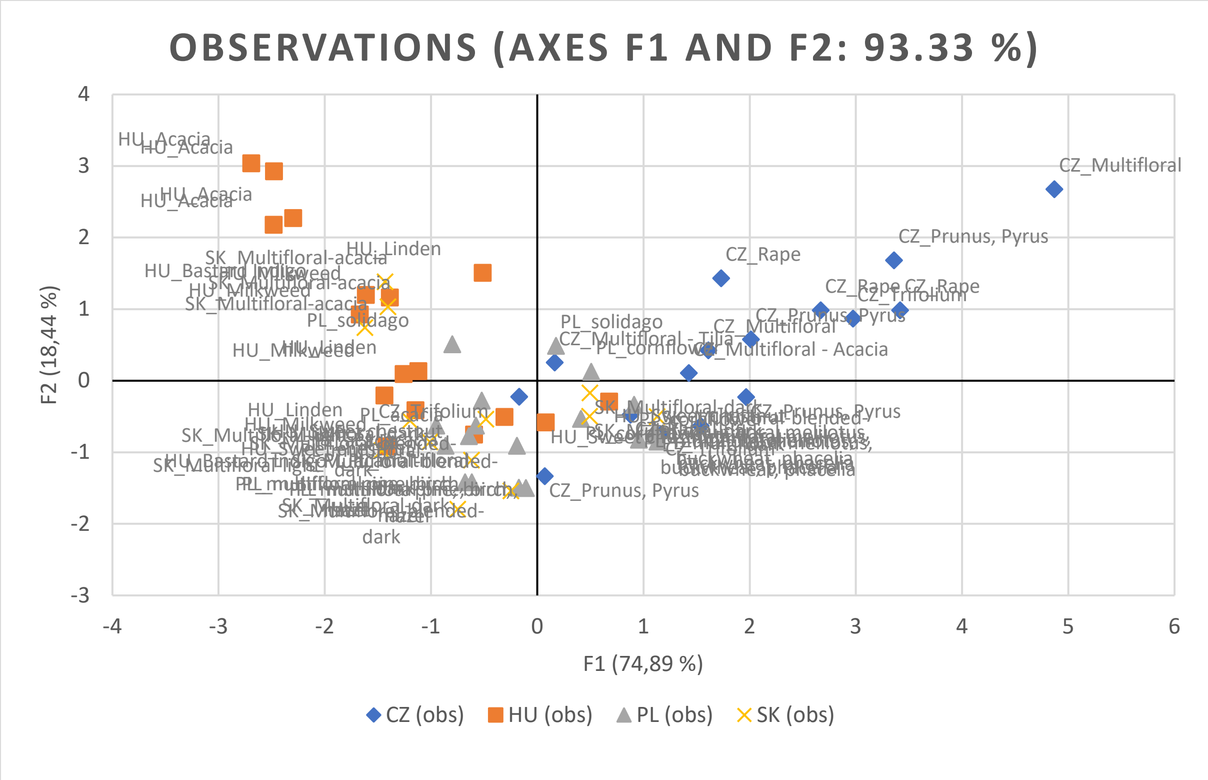


Figure 20: Plot of linear discrimination analysis for color analysis.

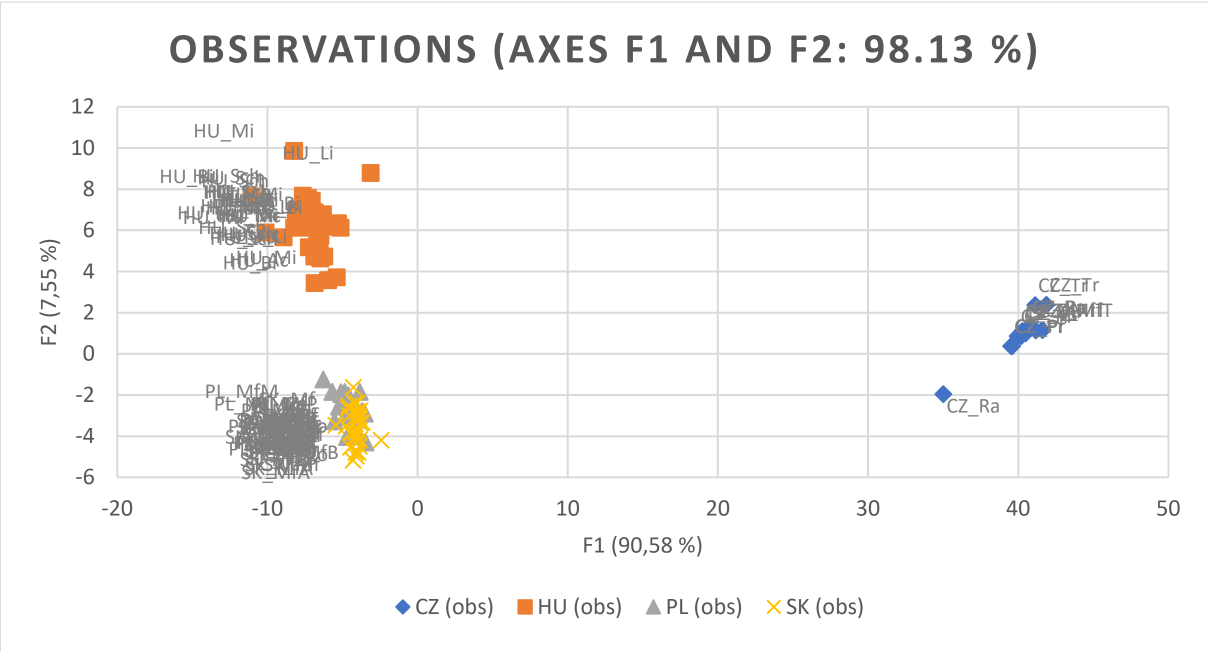


Figure 21: Plot of linear discrimination analysis for melissopalynology.

Quality location prediction through GIS

The influence of the location is reflected in the bee product, especially honey. The area from 7 to 28 km^2 is representative for the bee colony and is given by the average flight distance. Previous studies have confirmed that bee colonies accumulate different matrices in the product depending on the habitat. In the past it has been used to predict environmental pollution from anthropogenic or natural sources (Crane 1984; Svoboda 1961). It has also been confirmed that there is a relationship between the mineral composition of the soil and plants (Joy et al. 2015; Kaiser et al. 2012; Pongrac et al. 2019). For sustainable beekeeping it is also important that soil type has an effect on nectar production, which is an important source of carbohydrates (source of energy) for the bee. The positive effect on nectar production has been confirmed for Ca, Mn and Fe (Cardoso et al. 2012; Wielgolaski 2001). The important effect of soil is also on pollen production, where calcium, phosphorus, humus, K, Fe and Mn increase the number of flowers on the plants. The higher number of flowers is a prerequisite for a higher amount of pollen collected by the bee, which is an important source of protein for the bee colony. The great advantage of using GIS is also the possibility to predict the botanical sources in the bee habitat. For this, it is possible to use land cover information freely available in national or international databases such as Corine Land Cover (EEA 2018). The predictable botanical taxa are Helianthus sp., Robinia sp., Campanula sp., Brasica sp., Aesculus sp., Rhamnus sp., Lotus sp., Thymus sp., Lythrum sp., Phacelia sp., Phagopyrum sp., Aruncus. These botanical taxa are sources of both nectar and pollen. Some flower in spring, others in autumn. The longer period of nectar and pollen sources during the year is also important for sustainable beekeeping. Minimal periods without food sources also have an impact on the health status of the bee colony.

For the determination of the predictive parameters, 32 honey samples were used. Melissopalynological analysis and mineral profile were measured. The area of land use and soil type was analysed in 28 km^2 around each colony.

The results were partially published in the studies: Schmidlová, S.; Javůrková, Z.; Tremlová, B.; Hernik, J.; Prus, B.; Marcinčák, S.; Marcinčáková, D.; Štarha, P.; Čížková, H.; Kružík, V.; et al. Exploring the Influence of Soil Types on the Mineral Profile of Honey: Implications for Geographical Origin Prediction. *Foods* **2024**, *13*, 2006. https://doi.org/10.3390/foods13132006. (Annex 9.)

Pospiech, M., Bartlová, M., Prus, B., Titěra, D., Kružík, V., Čížková, H. Predikce zdrojů snůšky včel pomocí geografických informačních systémů. In: Apidologická konferencia BeeConnected 2024, Košice: Univerzita veterinárskeho lekárstva a farmácie v Košiciach, 2024, pp 18. ISBN 978-80-8077-819-4. (Annex 10.)

In summary, this work has confirmed the ability of the GIS system to predict the location of bee hives. In our research we confirmed the importance of pasture and non-irrigated arable land as a source of botanical taxon able to ensure the amount of nutrition for bee colony during the year. However, the spring source of nectar and pollen is based on sowing procedure and it can change annually and also depends on agricultural policy in each Visegrad country. The detailed correlation between land cover and botanical taxa is shown in Figure 26 and Figure 27. Soil type had influence on B, Ca, Mg, Ni, Mg and Mn in honey. From the mentioned mineral compounds the Ca, Mn and Fe is predictable also for nectar and pollen production in bee habitat. Our results show that high amounts of these minerals corresponded with anthrosol, kastanozem soil type. In this reason they challenge in bee habitat is prerequisite for good nectar and pollen production.

The predictive model was calculated using the following algorithm (calculations and analyzes were performed in QGIS):

(1) Loading input layers and pre-processing data.

a. loading country borders CNTR_RG_01M_2020_3035

b. designation of the countries participating in the project (CZ; HU; PL; SK)

c. loading Corine Land Cover layers in shp format: U2018_CLC2018_V2020_20u1_PL; U2018_CLC2018_V2020_20u1_HU; U2018_CLC2018_V2020_20u1_SK; U2018_CLC2018_V2020_20u1_CZ

d. loading vector layers European Soil Database v2.0 (vector and attribute)

(2) Loading the coordinates of the apiary locations, coordinates in the WGS84 system.

(3) Generating buffers at a distance of 3 km from the apiary locations using geoprocessing tools, buffer command (Figure 23).

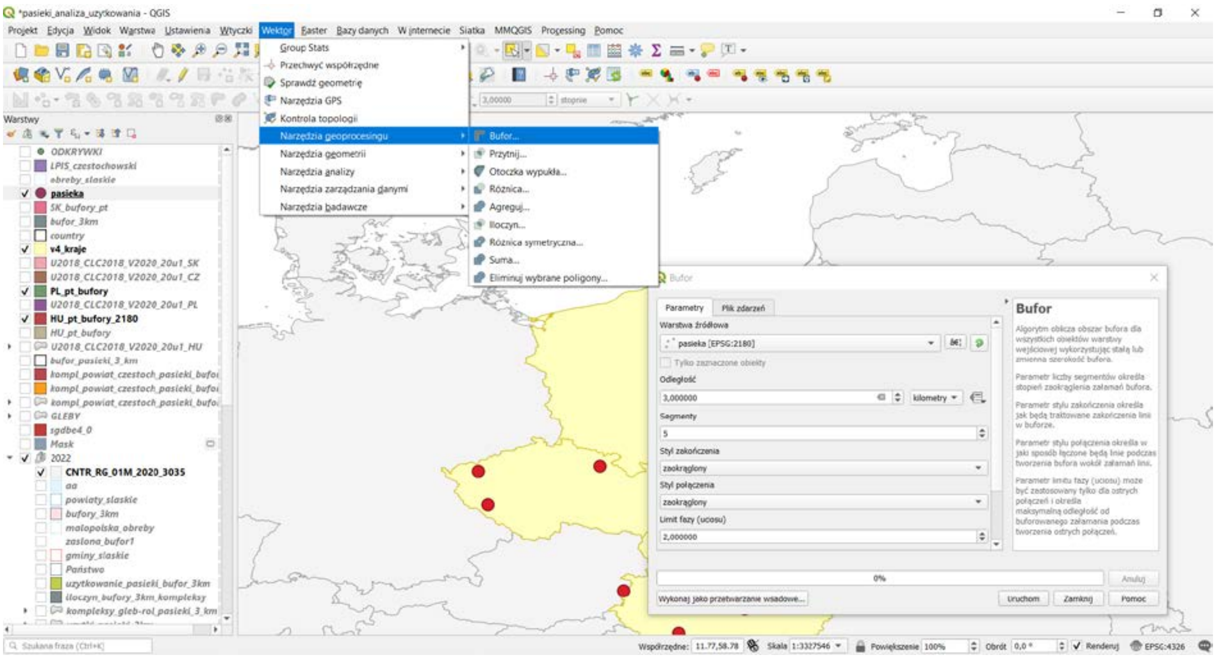


Figure 22: Buffers generating.

(4) Preparation of the spatial product between buffers designated at a distance of 3 km from the locations of apiaries and the land cover layer for Corine Land Cover data, for each of the countries participating in the project.

(5) Calculation of reclassified areas using the area calculator (Figure 23) for land cover data in zones related to the location of apiaries (3 km).

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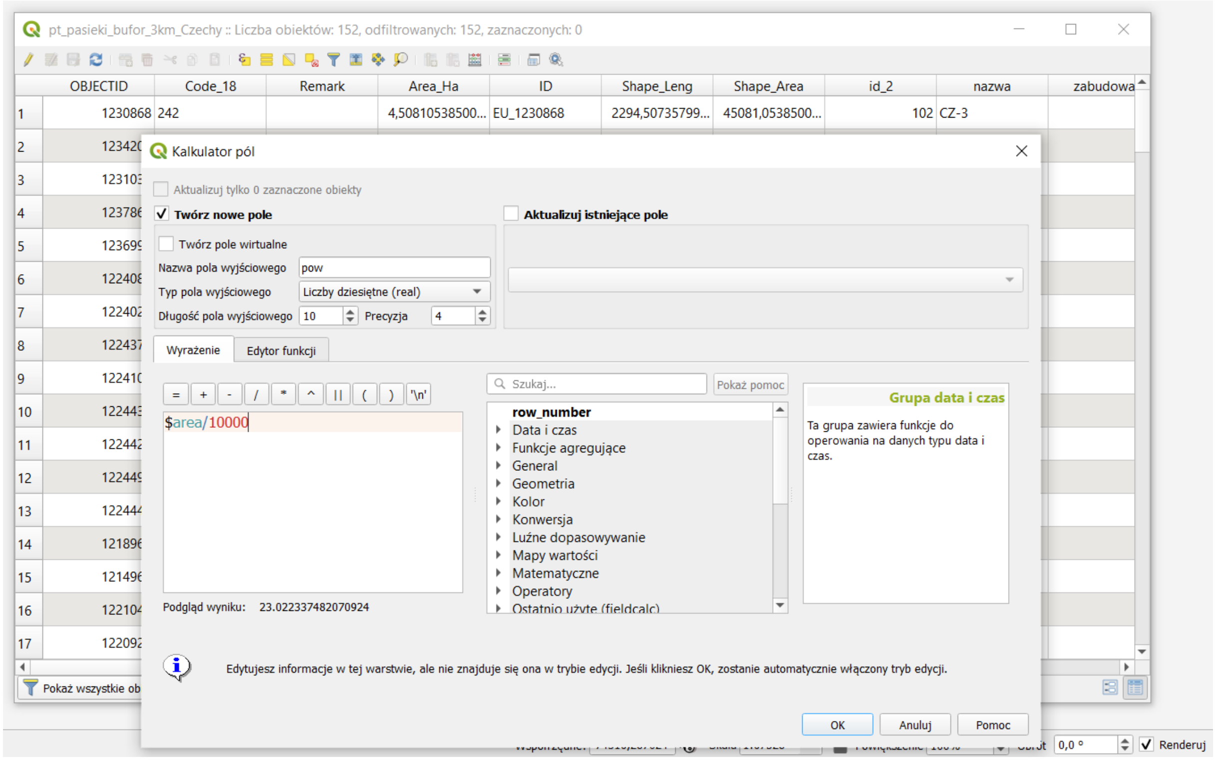

Figure 23: Area calculation for bee hive location.

(6) Calculation of the land cover area based by classified land cover types in Corine Land Cover using the GroupStats plug-in, for each of the analyzed countries (Figure 24).

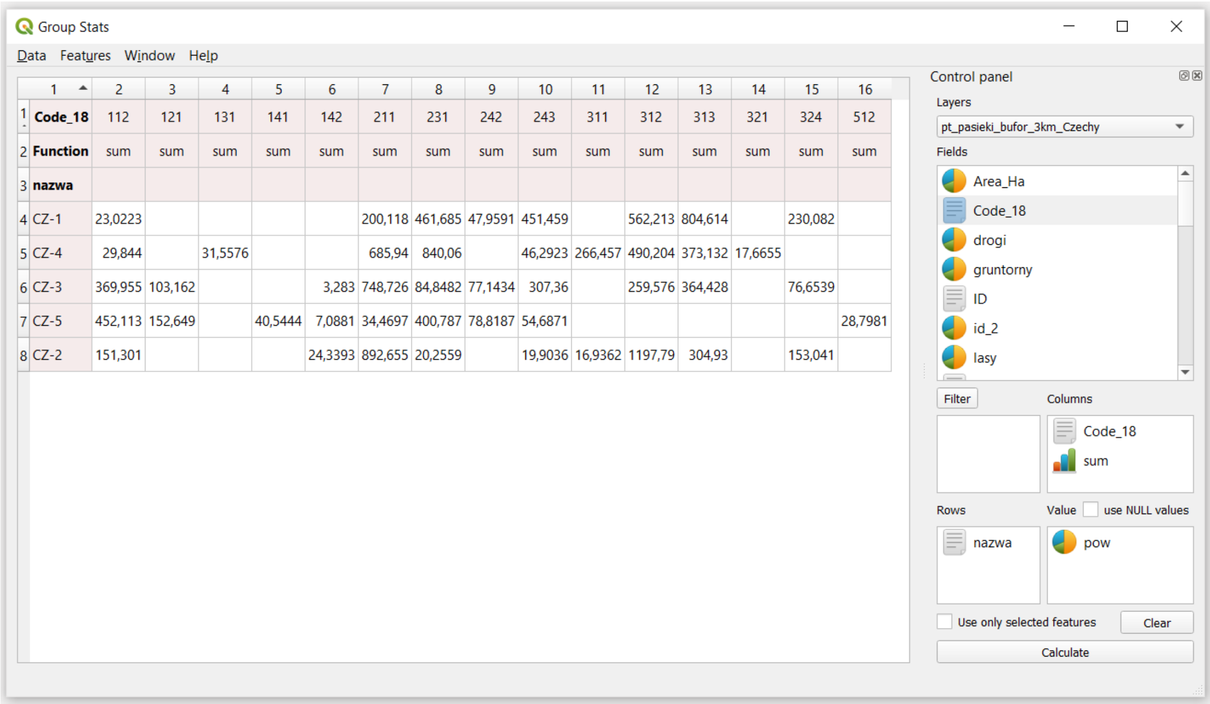

Figure 24: Land cover area calculation.

(7) Calculation of land cover statistics in the countries participating in the project in Microsoft Excel and classification of land cover forms into: built-up areas, forests, green areas, arable lands, waters, roads, waste lands.

(8) Preparation of the spatial product between buffers designated at a distance of 3 km from the locations of apiaries and the European Soil Database v.20 layer, for each of the countries participating in the project (Figure 25).

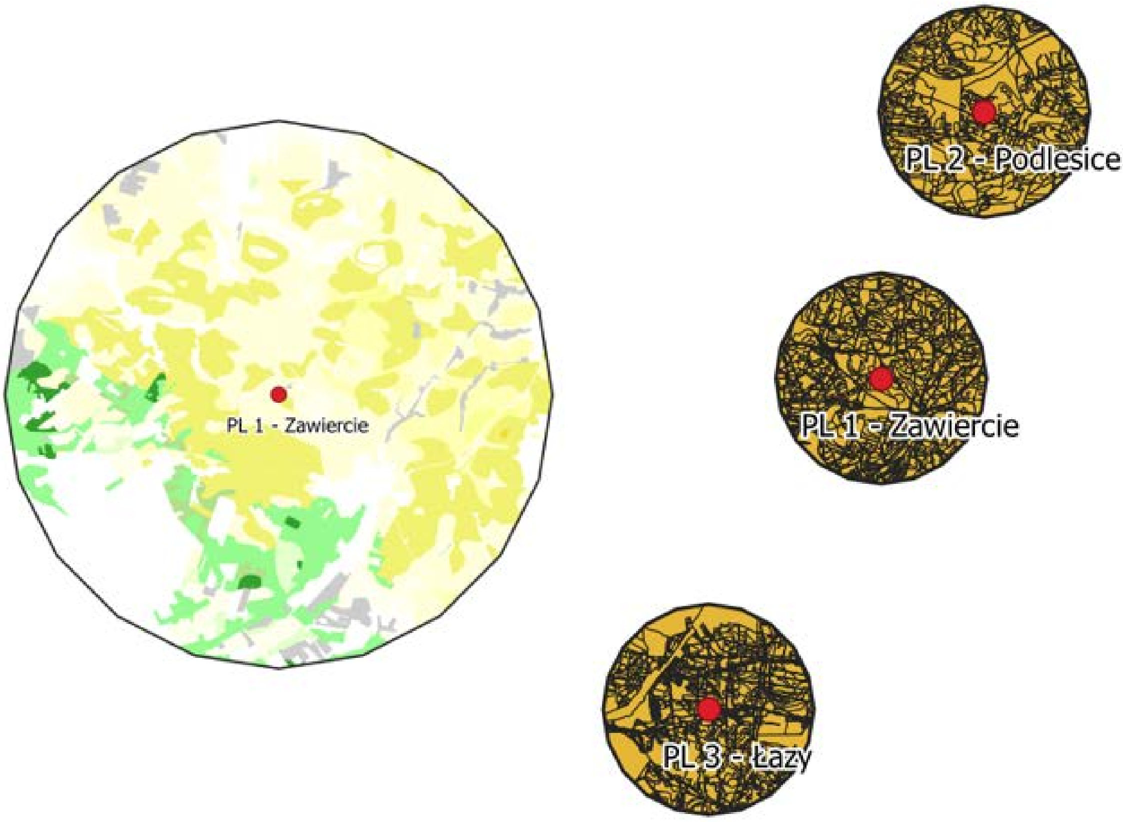

Figure 25: Example of image data preparation with selected buffer.

(9) Calculation of reclassified areas using the field calculator for soil bonity data in zones related to the location of apiaries (3 km)

(10) Calculation of the soil bonity area using the GroupStats plugin, for each of the analyzed countries

(11) Calculation of soil bonity statistics in the countries participating in the project in Microsoft Excel

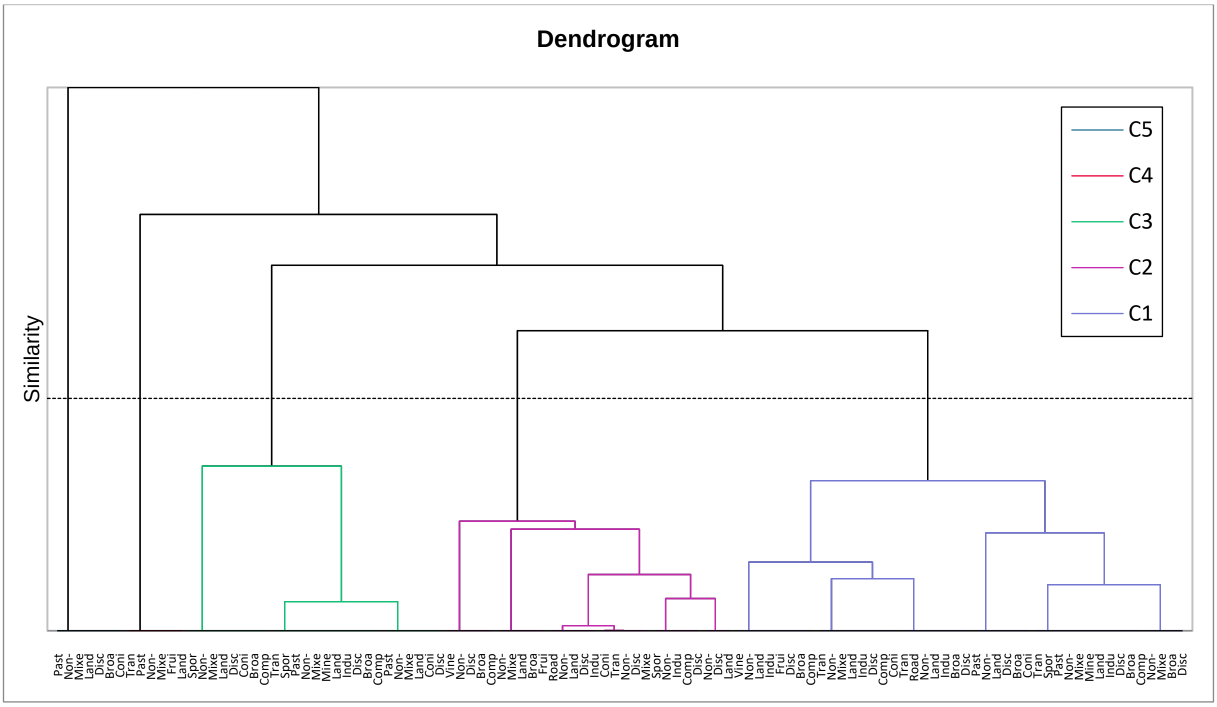

Figure 26: Dendograph of land cover and botanical taxa.

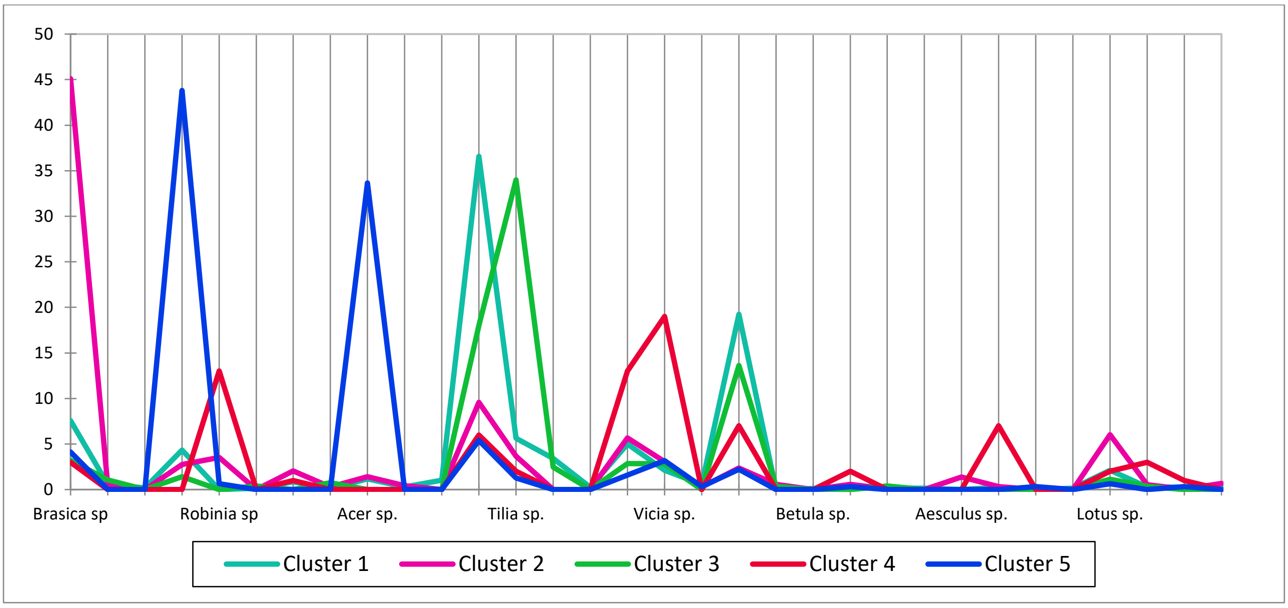

Figure 27: Cluster plot of botanical taxa.

5. Conclusion

- **Differences between declared and analytically confirmed honey origin** : Significant differences were observed between beekeepers’ declarations and analytical identification of honey origins, highlighting the necessity of analytical methods for accurate determination. This discrepancy affects honey quality protection and compliance with legislation. Notably, there is a 23% higher identification of monofloral honey analytically than by beekeepers, indicating the need for better methods to classify monofloral honeys in line with the European Directive 2024/1438. Further research should explore the environmental and agricultural factors influencing monofloral honey production.
- **Relationship between pollen taxa and land cover**: A correlation between the occurrence of pollen taxa in honey and specific types of land cover, as per the European CORINE system, was confirmed. Strong correlations were found for certain pollen taxa with native landscapes and urban green areas. Type 3 classification (according to CLC classes) showed the highest correlation, making it suitable for further studies, unlike Type 1 (according to CLC classes).
- **Impact of land cover on honey components**: Water content, acidity, HMF, and diastase activity in honey showed no relation with land cover, as these are processing-related parameters. Carbohydrates, like sucrose, fructose, turanose, maltose, and melezitose also lacked clear land cover relationships. However, glucose and trehalose showed interesting variations with land cover. Melissopalynological analysis indicated specific pollen types' presence in different land covers. The prediction of land cover from honey components showed a low correlation coefficient rate (CCR) of 45%, this aspect necessitating further research.
- **Mineral correlations in honey and soil**: Strong correlations were found between minerals in honey (Mg, Ni, Cu, Cd, As) and soil properties (organic carbon, humus, acidity). This correlation was not revealed for essential plant nutrients such as Ca and K, due to human agricultural activities where these minerals are used as fortifiers.
- **Variability in honey composition**: Individual bee colonies produce honey with varying physico-chemical compositions and colour characteristics, aligning with beekeepers' observations. In Slovakia, the highest agreement in results was 43% for light flower honey from Stakčín, while Poland and Hungary showed similar variability in maximum 36%. Differences could be attributed to bee community preferences and colony development stages influenced by multiple factors.
- **Characterization of Visegrad honeys**: Differences in honey parameters among Visegrad countries were confirmed, with a detailed characterization of physico-chemical and melissopalynological parameters. This characterization aids in protecting the designation of origin and supporting sustainable beekeeping. Multivariate analyses demonstrated high regional differentiation ability for physico-chemical parameters (89%), mineral profile (86.5%), and colour (66.2%).
- **GIS System for beehive location prediction**: The GIS system effectively predicted beehive locations, emphasizing the importance of pasture and non-irrigated arable land for year-round bee nutrition. Nectar and pollen sources vary annually due to agricultural policies. It was also confirmed that soil type influences the mineral content of honey. Higher levels of Ca, Mn and Fe with specific soil types such as anthrosol and kastanozem being crucial for good nectar and pollen production.

These conclusions highlight the importance of accurate honey classification, the significant impact of land cover and soil on honey composition, and the potential of advanced analytical and GIS methods in apiculture research and practice.

6. References

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JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal
Published by Faculty of Biotechnology and Food Sciences

COMPARISON OF BEEKEEPERS' AND ANALYTICAL DETERMINATIONS OF HONEY ORIGIN

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https://doi.org/10.55251/jmbfs.9887

ARTICLE INFO

Received 10. 2. 2023
Revised 12. 2. 2024
Accepted 29. 2. 2024
Published 1. 6. 2024

Regular article

OPEN ACCESS

ABSTRACT

Honey is a natural sweetener evaluated in accordance with Council Directive 2001/110/EC. 336 honeys from Czech hobby beekeepers were evaluated in this work. The honeys were classified by the beekeepers using questionnaires, and all samples were subjected to laboratory analysis using physico-chemical and melissopalynological methods. The honey samples were categorized by the beekeepers into blossom honeys (n=272), honeydew honeys (n=32), and blended honeys (n=32). Statistically significant differences between beekeepers' and analytical determinations of honey origin were confirmed. For blossom honey, incorrect classification was due to hight electric conductivity (39%), hight moisture (29%), low F+G (14%), and high sucrose content (0,4%). For honeydew honey, incorrect classification was mainly due to low electric conductivity (100%). For blended honey due to high electric conductivity (3.2%) and high acidity (3.2%). Our results show that although the beekeeper has a great deal of information at his disposal for the proper classification of honey, the determination of a wide range of honey contents and properties is always crucial. The cumulative assessment of blossom honeys also showed that there are more monofloral honeys in the country than beekeepers themselves identify. The 6.8% and 23.0% of blossom honey was in compliance with the definition for monofloral honeys for upper and lower limit according to Czech and German regulation.

Keywords: melissopalynology; monofloral honey; beekeepers practice

INTRODUCTION

Currently, the consumer can choose of a whole range of kinds and types of honey, which are defined in the Czech Republic in Decree No. 76/2003 Coll. **(Decree, 2003)** which incorporates European Directive No. 110/2001 **(Directive, 2001)**. The Directive describe honeys depending on their origin into blossom, honeydew and their combination, i.e. blended honeys. Blossom honeys can be classified according to the botanical taxa from which they come, then we talk about monofloral honeys. Based on honey origin the directive classifies honeydew honey from abroad, however, in the Czech Republic honeydew honey are not divided according to the type of aphids from which it comes. Considering the climatic and botanical conditions in the Czech Republic, it is said that it is not easy to produce monofloral honey. There is no honey in the Czech Republic that is protected by any of the international quality marks, nor by a national mark that protect the region of origin of the honey. Meanwhile, in the European Union (EU) there are 8 honeys with the quality mark of protected geographical indication and 30 with the mark of protected designation of origin. At the national level, regional delimitation is provided by the national standard "Český med" (translated as "the Czech Honey") that defines stricter physical and chemical conditions for traditional Czech honey and mainly narrows the origin of honey down to the territory of the Czech Republic **(Kamler *et al.*, 1999)**. From the point of view of Regulation No. 1169/2011, the designation by the name of the country is also binding and such labelling of the food must not be misleading, so the honey must come from the given country if it bears its name **(Regulation, 2011)**. The amount and type of pollen present in the honey is important for determining its botanical origin. But the dominant taxon is not necessarily the defining taxon – i.e. the specific taxon – of the monofloral honey. The reason is the different pollen-producing capacity of botanical taxa, as well as the ability of pollen to get on the body of the bees and then into honey. Pollen-producing capacity of the main taxa important for bees is summarized in a Polish study **(Demianowicz, 1964)** which is still used today. During a nectar collection period, bees utilize all available botanical taxa within a reachable range. Therefore, honey with a specific taxon content of more than 45% is generally considered to be monofloral honey. However, this rule is not accurate for taxa that are characterized by high (*Brassica sp.*) or low (*Robinia pseudoacacia*) pollen-producing capacity **(Anklam, 1998)**. Therefore, the basic assumption is to examine a minimum amount of pollen grains in honey in order to eliminate sampling error by systematic examination as described in an European study **(Ohe *et al.*, 2004)**. Identifying botanical taxa microscopically is difficult, although many botanical taxa are identified to genus level based on the morphological structure of the pollen grain. For this reason, taxa are classified according to their frequency of occurrence as predominant pollen, secondary pollen, important minor pollen, minor pollen, and present pollen **(Louveaux et al. 1970)**. Generally, the first two groups determine the origin of the honey. Important minor pollen can determine the origin of honey in some exceptions, such as Robinina pseudoacacia or Citrus spThe expected abundance of the main taxon may vary according to the data of different authors **(Beckh & Camps, 2009; El-Labban, 2020; Persano Oddo *et al.*, 1995; Persano Oddo & Piro, 2004)**, as well as according to national standards. For the Czech Republic, a national standard has not yet been established, however, values taken from the German specification are mainly used **(Beckh & Camps, 2009)** and a range of specific pollen taxa included in the Czech National Methodology for Pollen Analysis is also available **(Pospiech *et al.*, 2021)**. . In view of the above, it is important not only to identify pollen grains, but also to interpret the results correctly. In addition to the pollen representation of specific taxa, monofloral honeys must also be in accordance with physico-chemical parameters and sensory characteristics. From the physico-chemical characteristics, the most important for determining the origin of honey is the electric conductivity (el. cond.) and the sum of fructose and glucose (F+G), which divides honeys into blossom and honeydew honeys. The ratio of fructose and glucose (F/G) is also an important parameter especially for determining its botanical origin. Of the sensory parameters, colour, taste and aroma are important. In addition to the verbal description, the colour is also expressed analytically in the PFUND unit. The mentioned physico-chemical and sensory parameters for some monofloral honeys are described in the German specification, recommendations of the International Honey Commission and in professional literature **(Beckh & Camps, 2009; Persano Oddo *et al.*, 2004; Persano Oddo & Piro, 2004; Piana *et al.*, 2004)**.
The aim of this study was the comparison of the botanical origin of honey by beekeeper´s declaration and on the basis of physico-chemical parameters and melissopalynological analysis of honey. All the honey samples were from the Czech Republic and collected by hobby beekeepers.

MATERIAL AND METHODS

As part of this work, 336 honey samples from hobby beekeepers from the Czech Republic were evaluated. The honey was taken in the form of mature honeycombs and individually extracted under controlled conditions to prevent any cross-contamination between the processed samples.. It was mainly the first and second collection periods, in some localities the third collection was also included. The honeys were collected and analysed in 2019 to 2021. The honey came from hobby beekeepers, who voluntarily participated in this study. Data on the botanical origin of honey came from a questionnaire survey where each beekeeper was asked the questions below:

1. Is this blossom or honeydew honey?
2. If blossom honey, is it a polyfloral or monofloral honey? If monofloral honey, what is the dominant botanical taxon?
3. Unclassified honey samples were ranked as blended honey.

To confirm the questionnaire survey, the honeys were further analysed in order to confirm the beekeepers' statements. The limit for the analytical method used was taken from the European Directive No. 110/2001 (**(Directive, 2001)**. For monofloral honey upper and lower limit was used. These limits are taken from **(Beckh & Camps, 2009; Pospiech *et al.*, 2021)**
The following analyses were performed.

Determination of water content – the tempered and homogenized sample of honey was applied to the optical prism of a digital Abbe refractometer RM 40 (Mettler-Toledo, CH) with the whole tempered to 20 °C. The refractometer was calibrated using the refractometric index of distilled water before use. Each sample was measured in duplicate. The method was performed according to the recommendations of the International Honey Committee (IHC) **(Bogdanov, 2009)**. This parameter was only used for quality determination and was not used for determination of honey origin.

Determination of electrical conductivity (el.cond.) – the honey sample was weighed to represent 20g of honey dry matter. The sample was added to 100 ml of distilled water at a temperature of 20 °C. The el. cond. was determined in the conductivity cell of the conductometer Multi 9310 IDS (WTW GmbH, GER. The electrode used was IDS Tetra Con 925 (WTW GmbH, GER). The method was performed according to the approved IHC procedure **(Bogdanov, 2009)**.

Determination of free acidity was provided by alkalimetric titration to a final pH of 8.3. An automatic titrator T5 (Mettler-Toledo, CHE) and an electrode DGi115-SC (Mettler-Toledo, CHE) The method was performed according to the approved IHC procedure **(Bogdanov, 2009)**.

Determination of diastase – diastase activity (DN) was determined by Phadebas method using a commercially available kit. The method was carried out according to the instructions supplied with the kit **(Bogdanov, 2009; Phadebas, 2018)**.

Determination of saccharides content – a sample of honey weighing 2.5 g was dissolved in 12.5 ml of a 25% aqueous methanol solution and made up to 50 ml in a volumetric flask. Before analysis, samples were filtered with a 0.45 µm membrane filter. The content of mono- and di-saccharides was determined by the HPLC method (high performance liquid chromatography) with RI detection (detection based on changes in the refractive index). The flow rate of the mobile phase was 1.2 ml/min, the temperature of the detector was 35°C, the temperature of the column 35°C, the volume of the dosing loop 10 µl. The method is based on the approved IHC methodology **(Bogdanov, 2009)**.

Melissopalynological analysis – before analysis, the samples were homogenized and tempered at a temperature of 40°C until complete dissolution. 5 g of the sample was weighed into 20 ml of tempered water. The quantitative method of filtering honey according to **(von der Ohe *et al.*, 2004)**. Briefly, a filter of 3µm, Ø 25mm (Millipore, Merc, USA) was applied, filtration was performed by Eisco™ Glass Filtration Assembly (Fisherscientific, USA). After drying, the filter was mounted using solacryl on a 76 x 26 mm glass slide. The samples were analysed under the Eclipse Ci-L microscope (Nikon, JPN) with motorized stage of Proscan III (Prior, USA). Images were captured by the DFK 23U274 camera (Imaging Source, GER). The pollens were classified by an expert from super resolution pictures.

Statistical analysis – nonparametric McNemar's test (Contingency table test) was used for comparison, significance level was alpha 0.05. McNemar's test compared 2 values with binary responses for randomized complete blocks. Xlstat 2022.4.1.1370 software was applied. Results which are not in agreement between beekeepers declaration and analytical results (inconsistent results) are interpreted as relative value calculated from inconsistent results, not from all evaluated samples.

RESULTS AND DISCUSSION

According to legislative requirements, honey can be divided into blossom honey and honeydew honey. The division reflects the origin of honey, i.e. the source from which a significant part of the nectar comes. Blossom honey is honey produced from the nectar of plants. Honeydew honey comes mainly from the excretions of aphids (*Hemiptera sp.*) sucking on plant tissue. Honey can also be further labelled by its origin as monofloral and polyfloral **(Decree, 2003; Regulation, 2001)**. The third category defined by national legislation **(Decree, 2003)** is blended honey that represents honey containing an undefined ratio of nectar and honeydew. It could also be said that it is a transition between blossom and honeydew honey. Such honey has different characteristics and, given the diversity, it is not easy to be defined, therefore both, the national legislation as well as the professional literature, do not define a specific parameter that would be typical for this type of honey. European Directive **(Regulation, 2001)** considers "blends of honeydew honey with blossom honey" to be honeydew honey and it must meet its minimum requirements. To identify the origin of honey, the beekeeper applies his knowledge of nectar-producing plants in the vicinity of the hives, but commercially defined physico-chemical parameters and melissopalynological analysis are used to determine/confirm the origin of honey nectar. A comparison of blossom honey origin indicated by beekeepers and results based on physico-chemical parameters and melissopalynological analysis is presented in **Table 1**.

Blossom Honey

McNemar's test confirmed a statistically significant difference ($p < 0.05$) between the honey samples determined by the beekeeper and the laboratory analysis. The result clearly confirmed that sensory evaluation, knowledge of the location, observing the flight of bees, as is commonly done by beekeepers, does not allow a clear identification of the origin of honey. Relatively speaking, 20% of blossom honeys were not correctly identified by beekeepers.

Table 1 Comparison of beekeepers' and analytical determinations of blossom honey

		Results of analysis		
		Blossom	Non-Blossom	Total
Beekeepers declaration	Blossom	205 (61.0%)*	67 (19.9%)	272 (81.0%)
	Non-Blossom	27 (8.0%)	37 (11.0%)	64 (19.0%)
	Total	232 (69.0%)	104 (31.0%)	336 (100)

*relative expression of the frequencies

Inconsistency with analytical values was most often (39% of inconsistent results) due to the high el. cond. of honey, which is a maximum of 0.8 mS/cm for blossom honey **(Regulation, 2001)**. Other reasons were the low F+G content (14%), which is legislatively limited to a minimum content of 60% for blossom honeys and high water content of 29% honey, which is legislatively limited to a maximum of 20% **(Decree, 2003; Regulation, 2001)**. The physico-chemical parameters of blossom and non-blossom honey are shown in **table 2**.

Table 2 Physico-chemical parameters of blossom honey

Physico-chemical parameters	Blossom	Non- Blossom
Water content (%)	17.7±1.5	18.0±2.7
Electrical conductivity (mS.cm-1)	0.4±0.2	0.8±0.4
Free acidity (meq/kg)	19.6±7.7	28.5±10.2
Diastase (DN)	25.6±8.5	24.2±6.9
F+G (%)	73.0±4.9	65.5±7.9

DN – diastase number

In 16% of honeys, more than two parameters were inconsistent with the analytical values. In one case only a high sucrose content was recorded (9.5 g/100g). The botanical profile of this honey (45% lime, 0% acacia) did not correspond to *Robinia pseudoacacia* honey and cannot be considered *Robinia pseudoacacia* honey from the legislative point of view, where an exception of 10 g/100g of sucrose content is allowed **(Regulation, 2001)**.
For blossom honey, legislative allow the labelling as floral or vegetable origin in case that honey comes mainly from the indicated source with condition that sensory, physico-chemical and microscopic characteristics are in accordance with botanic source. For blossom honey, the beekeepers were also asked to determine its botanical origin in the case of the assumption of monofloral honey. The agreement with the beekeepers' statements is shown in **Table 3.** Determining monofloral honeys is not easy, and therefore, both in the literature and in national recommendations or standards, a certain range of achievement values is allowed for them. In particular, this applies to the range in the pollen content, but the range can also be for some physico-chemical parameters. Therefore, the agreement between the determination of honey by the beekeeper and the analytical values is expressed separately for the upper limit and lower limit (**Table 3.**).

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Table 3 Comparison of beekeepers' and analytical determinations of monofloral honey

		Result of analysis					
		Upper Limit			**Lower Limit**		
		Agreement	Disagreement	Total	Agreement	Disagreement	Total
Beekeepers declaration	Agreement	0	7	7	2	5	7
	Disagreement	18	311	329	61	268	329
	Total	**18**	**318**	**336**	**63**	**273**	**336**

Upper and lower limits of pollen content and physico-chemical parameters **(Beckh & Camps, 2009; Pospiech *et al.*, 2021)**

McNemar's test confirmed a statistically significant difference between the monofloral honeys determined by the beekeeper and the laboratory analysis ($p < 0.05$) for the lower as well as upper limit. The calculated value of the test was ($p = 0.045$) for the upper limit and ($p < 0.0001$) for the lower limit. But it should also be mentioned that there can be differences even between laboratory methods, especially with regard to non-harmonized melissopalynological analysis. In Europe, different laboratories may achieve different results on pollen content. For example, in a Spanish study, interlaboratory differences reached 5-54% for *Brassica sp*., 8.7-31% for *Coriandrum sativum*, 0-17% for *Castanea sativa* and 75.7-99% for *Eucalyptus sp*. **(Escriche *et al.*, 2023)**. In order to minimize errors, several studies have been developed that deal with the issue of the melissopalynological method **(Bogdanov, 2009; Jones & Bryant, 1992, 2001; Louveaux *et al.*, 1970; Low *et al.*, 1989)**. One recommendation is to count at least 300 pollen grains, or better 500-1000 pollen grains per sample **(Silici & Gökceoglu, 2007; Stawiarz & Wróblewska, 2010; Terrab *et al.*, 2004)**. In order to verify the method, it is then advisable to at least meet the repeatability and reproducibility of the results, as defined in the IHC recommendation **(Ohe *et al.*, 2004)**. Or it can also be use mathematical models that evaluate all possible combinations of fields of view of the examined honey sample **(Pospiech *et al.*, 2021)**.

An important fact resulting from this assessment is that there is potentially a larger amount of monofloral honey in the Czech Republic than beekeepers estimate for blossom honeys. In relative terms, 6.8% of blossom honeys with an upper limit and 23.0% of blossom honeys with a lower limit of specific taxa pollen content and compliance with physico-chemical parameters could be considered as monofloral. Their representation is shown in **Table 4** including the specific taxon for monofloral honey.

Table 4 Monofloral honey classified according to upper and lower limit of pollen content

	Total	
Limit	Upper Limit	Lower Limit
Acacia honey	0	1
Clover honey	0	6
Lime honey	4	13
Mustard honey	1	1
Honey from fruit trees	2	2
Dandelion honey	0	1
Buckwheat honey	0	1
Rapeseed honey	10	34
Sunflower honey	0	1
Goldenrod honey	1	1
Total	18	61

Of the analysed blossom honeys from the Czech Republic, rapeseed honey was most often confirmed. Another monofloral honey with a greater occurrence was lime honey. About half of that amount was clover honey, which is not often described but is common in countries with more grassland, such as Ireland **(Downey *et al.*, 2005)**. Clover honey may increase in the future in the Czech Republic with regard to the recognition of clover incarnate (*Trifolium incarnatum*) among registered agricultural varieties since 2018 **(Mezlík, 2019)**. The reason for growing clover incarnate, in combination with honey-producing blue tansy (*Phacelia tanacetifolia*) and non-honey-producing annual ryegrass (*Lolium multiflorum*), is that they represent a combination with the lowest erosion factor, and on the contrary, they enrich the soil with atmospheric nitrogen and thus improve the yields of the later crops **(Kincl *et al.*, 2022)**.

Monofloral rapeseed honey was confirmed in 34 cases. While the upper limit, i.e. 80% or more rapeseed pollen, would correspond to 10 honey samples, the lower limit, i.e. more than 60%. In addition to the pollen profile, this honey must also meet physico-chemical parameters. Specifically, it is a el. cond. lower than 0.25 mS/cm and F/G ratio lower than 1.05 **(Beckh & Camps, 2009; Persano Oddo & Piro, 2004)**. The rapeseed honey samples in this study had an average el. cond. of 0.21 mS/cm and the F/G ratio was 1.00.

Acacia honey has been confirmed in one case. This honey was declared by the beekeeper as floral, but the beekeeper did not provide a botanical definition. In addition to the minimum pollen content (10%), acacia honey must have an F/G ratio greater than 1.5 and a el. cond. less than 0.20 mS/cm. For this honey, the el. cond. was 0.20 mS/cm and the F/G ratio was 1.5. Both values were borderline. Of the analysed honey samples, three more met the requirement for the minimum amount of acacia pollen grains. However, these honeys did not meet the physico-chemical parameters for acacia honey.

Lime honey is a typical monofloral honey for the Czech Republic. This honey is characterized by a strong aroma and is popular for many consumers. From the point of view of lime honey production, however, compared to other monofloral honeys, there is a difference in the source of sweet secretions. Lime tree is not only a nectar-producing tree, but is also a good source of honeydew. A higher acidity of 23.5 meq/kg, or a pH of 4.4, is therefore typical for these honeys. With regard to honeydew, this honey is also characterized by a higher el. cond., with an average of around 0.63 mS/cm **(Persano Oddo & Piro, 2004)**. According to the German standard, the minimum el. cond. is 0.20 mS/cm, and an F/G ratio of 1.0 and above **(Beckh & Camps, 2009)**. Interestingly, these values are not in accordance with the already mentioned German standard, which is more liberal in this case. All analysed honeys in this study with a lime tree pollen content above 10% also met the physico-chemical parameters. They can therefore be considered monofloral honeys, if the sensory properties are also suitable. For lime honey in this study, the average el. cond. was 0.65 mS/cm and F/G ratio was 1.2, acidity was 26.98 meq/kg. The pollen content of the honeys in this study was above 20% in only four honeys, which confirms the lower pollen-producing capacity of lime trees.

The situation is complicated with clover honey. There is no clearly defined pollen content for this monofloral honey, or the German trade standard states 60-70%. Compared to it, other literary sources report differences according to the type of clover, for example white clover (*Trifolioum repens*) 5-78% and red clover (*T. pratense*) 18%, and, in contrast, a Turkish study reports a range of 10-72% **(Dogan, 2008; Downey *et al.*, 2005)**. There are also differences in the physico-chemical parameters, where the German standard states el. cond. less than 0.40 mS/cm and F/G less than 1.25 **(Beckh & Camps, 2009)**, and literature reports el. cond. in the range 0.16-1.09 mS/cm, F/G in the range 1.1-1.5 **(Dogan, 2008)**. In the case of honeys from the Czech Republic, the average pollen content was 49%, the average el. cond. was 0.61mS/cm, F/G 1.16. The lower content of pollen in honey is most likely caused by different types of clover, when the German standard specifies them together for all, which does not appear to be an optimal limiting factor with respect to the literature.

Sunflower, buckwheat, and dandelion honeys were also occasionally recorded. For these honeys, there is a specification from a German standard, and a European descriptive study **(Beckh & Camps, 2009; Persano Oddo & Piro, 2004)**. For sunflower honey, a minimum pollen content of 30%, el. cond. 0.2 -0.4 mS/cm, F/G 1.2 is allowed. In the European descriptive study, however, a large variability in pollen content is allowed, ranging between 20-90% **(Persano Oddo & Piro, 2004)**. The recorded honey had a pollen content of 33%, a el. cond. of 0.22 mS/cm and an F/G of 1.0. Buckwheat honey is characterized by its specific sensory properties and is unacceptable to some consumers **(Kortesniemi *et al.*, 2017)**. The pollen content should be over 30%, el. cond. up to 0.3 mS/cm. The F/G ratio is not defined in the German standard**(Beckh & Camps, 2009)**, in the Serbian study, F/G in six samples was 1.4 **(Nešović *et al.*, 2020)**. The honey in this study had a pollen content of 49%, a el. cond. of 0.4 mS/cm, and an F/G of 1.1. With regard to its sensory properties, it is classified among monofloral honeys, the different el. cond. can be justified by the admixture of other taxa and honeydew. Fast crystallization and light colour are typical for dandelion honey. Dandelion honey has a minimum dandelion pollen content of 15% **(Beckh & Camps, 2009; Persano Oddo & Piro, 2004)**. Physico-chemical parameters for dandelion honey differ in the literature, similarly to lime honey, according to the German standard, the minimum el. cond. is greater than 0.40 mS/cm, the F/G ratio is less than 1.05. The European descriptive study reports an average el. cond. of 0.50 mS/cm and F/G ratio of 0.99 **(Beckh & Camps, 2009; Persano Oddo & Piro, 2004)**. The honey confirmed in this study did not meet the parameter of the F/G ratio, which was 1.07. However, we consider the honey to be monofloral due to ambiguous data in the literature and also due to the fact that differences in individual physico-chemical parameters have been confirmed between individual states for species honeys **(Juan-Borrás *et al.*, 2014)**.

Monofloral honeys from the flowers of fruit trees, goldenrod or mustard are less commonly described in the Czech Republic. For these types of honey, there is no officially or pan-European defined characteristic. When determining, we therefore apply the general assumption that more than 45% of the honey (nectar) comes primarily from this taxon **(Ohe *et al.*, 2004)**. Honey from fruit trees with regard to planting in the Czech Republic was expected, but the occurrence is relatively small and is due to the fact that nectar and pollen from early spring plants are used more for the development of the bee colony than for the creation of honey reserves.

However, in some regions and countries, the migration of bee colonies is used in a targeted manner in order to increase the yield of fruit trees (**Cunningham *et al.*, 2016**). It is then easier to obtain monofloral honey from fruit trees from these bee colonies. Goldenrod honey is characterized by a relatively high pollen content, ranging from 40 to 84%. This honey is typically light to watery white or amber. There are certain differences between the regions where this honey comes from (**Czigle *et al.*, 2022**). A lower amount of goldenrod pollen in monofloral honey is admitted by a Croatian study (28%), this study also reports the el. cond. of this honey as 0.39 mS/cm, the F/G ratio is 1.3 according to another study (**Zielińska *et al.*, 2014**). The goldenrod honey in this study had a pollen content of the main taxon in the amount of 64%, a el. cond. of 0.45 mS/cm, and an F/G of 1.3. Honey from mustard is also not ordinary honey and only a general rule can be applied to it, which is to meet the requirements for blossom honey and a minimum mustard pollen content of 45%. In this study, the pollen content reached 69%, el. cond. 0.27 mS/cm, F/G 1.0, F+G 72.79 g/100g.

Honeydew Honey

As in blossom honey, a comparison of the determinations of the origin by the beekeepers and analytical methods in honeydew honey samples confirmed a statistically significant difference by McNemar's test ($p < 0.05$). The result of the analytical determination and determination by the beekeepers is shown in **Table 5**.

Table 5 Comparison of beekeepers' and analytical determinations of honeydew honey

		Result of analysis		
Beekeepers declaration		Honeydew	Non-Honeydew	Total
	Honeydew	16 (4.8%)*	16 (4.8%)	32 (9.5)
	Non-Honeydew	39 (11.6%)	265 (78.9%)	304 (90.5)
	Total	55 (16.4)	281 (83.6)	336 (100)

*relative expression of the frequencies

Determination by beekeepers was incorrect in 50% of honey samples, as confirmed analytically. The reason for non-compliance with the legislative limit was always low el. cond. (100% non-compliant results) (**Directive, 2001**). In the case of the analytical methods, it was also a question of low el. cond. (99.7%), which is due to the fact that el. cond. is the decisive criterion for determining honey origin. Two honey samples (0.3%) did not meet the requirement for the maximum value of total acidity, which was above 50 meq/kg. The legislative parameter for the analytical determination of honeydew honey is also F+G, which is set at a minimum content of 45g/100g (**Directive, 2001**). The Physico-chemical parameters of honeydew and non-honeydew honey are shown in **table 6**.

Table 6 Physico-chemical parameters of honeydew honey

Physico-chemical parameters	Honeydew	Non-Honeydew
Water content (%)	17.0±1.2	17.6±1.3
Electrical conductivity (mS/cm)	1.1±0.2	0.5±0.1
Free acidity (meq/kg)	32.2±7.3	27.8±7.5
Diastase (DN)	25.5±6.6	29.6±9.9
F+G (%)	61.3±2.8	70.1±5.0

DN – diastase number

The lower permitted value of the sum of F+G in honeydew honeys than in blossom honeys is due to the different carbohydrate composition. Sucking insects, which make up a significant part of the sugar solutions used by bees for the production of honeydew honey, produce in addition to glucose and fructose other carbohydrates that subsequently become part of the honey. Honeydew honey can therefore contain 16 other carbohydrates in addition to glucose and fructose. The most represented include disaccharides (but not sucrose), trisaccharides and a certain percentage of tetrasaccharides. At the same time, it is not possible to say unequivocally which carbohydrates could be used to differentiate honeydew honeys, because they differ depending on two basic conditions. The first condition is the botanical species (**Pita-Calvo & Vázquez, 2018**), on which the insect sucks, and the second condition is the species of the insect itself (**Shaaban *et al.*, 2020**).

Blended Honey

Blended honey forms a transition between blossom and honeydew honey, both in terms of origin and variable analytical values. This group is the most difficult to characterize, and beekeepers rank here honeys for which they are not able estimate the source of the honey based on their practice. McNemar's test confirmed a statistically significant difference ($p < 0.05$) between the honey samples determined by the beekeeper and the laboratory analysis also for blended honey. The comparison results are presented in **Table 7**.

Table 7 Comparison of beekeepers' and analytical determinations of blended honey

		Result of analysis		
		Blended	Non-Blended	Total
Beekeepers declaration	Blended	30 (8.9%)*	2 (0.6%)	32 (9.5%)
	Non-Blended	288 (85.7%)	16 (4.8%)	304 (90.5%)
	Total	318 (94.6%)	18 (5.4)	336 (100%)

*relative expression of the frequencies

Honey incorrectly categorized by the beekeeper had high el. cond. (20.9 g/100ml) in one case and high acidity (62.8 meq/kg) in the other case, so the beekeeper incorrectly classified 6.3% of the honey in the blended honey category. From the legislative point of view, these honey samples cannot be considered as honey, but they could be used as baker's honey, where up to 25 g/100 ml of water and total acidity above 50 meq/kg are allowed. (**Directive, 2001**). The physico-chemical parameters of blended and non-blended honey are shown in **table 8**.

Table 8 Physico-chemical parameters of blended honey

Physico-chemical parameters	Blended	Non-Blended
Water content (g/100ml)	16.8±1.5	19.7±1.2
Electrical conductivity (mS.cm-1)	0.8±0.4	0.7±0.3
Free acidity (meq/kg)	29.3±9.7	41.9±21.0
Diastase (DN)	27.7±9.7	29.9±9.8
F+G (g/100ml)	67.1±7.5	70.8±4.8

DN – diastase number

An interesting fact about the blended honeys was that six of these honeys could be considered monofloral honeys. Rapeseed was the dominant taxon in four honeys, in varying pollen content (60-91%), and two honey samples contained a high amount of clover pollen reaching 45% and 33%. Honey samples with a rapeseed pollen content of more than 60% cannot be considered blended. Rapeseed is a nectar- and pollen-producing crop. The high pollen content therefore also indicates a large amount of rapeseed nectar in this honey. The situation is different for honey with the presence of clover pollen. Clover pollen is also an accompanying taxon for honeydew honeys, and for these honeys, the judging criterion would be the el. cond. of the honey. In our case, the el. cond. of honey with a pollen content of 33%, 0.84 mS/cm, which points to honeydew honey. Honey with a higher clover pollen content of 45% had a el. cond. of 0.66 mS/cm, which on the other hand points to blossom honey. These results confirmed that both honeydew and clover nectar contributed to the honey production in this sample. This finding is not surprising, as pollen is the main source of protein for bees and therefore, if it is available in the area, bees fly to pollen-producing plants even in the case of abundant honeydew. Primarily, pollen is stored by bees in special honeycomb cells, not in honeycomb cells with honey. However, pollen often gets into the honey, from the surface of the bees' bodies and also from the bees that process and thicken the nectar. The amount of pollen in honey can also be influenced by technological manipulation in the hive, when pollen from the pollen cells is then also stored in the honey (**da Fernandez & Ortiz, 1994**). Other taxa detected in this honey were lime tree 10% and forget-me-not 35%. Also, these taxa point to a collection from forest areas.

CONCLUSION

Statistically significant differences were confirmed between beekeepers' and analytical determinations of honey origin for all, blossom, honeydew as well as blended honeys. Overall, for blossom honey, honey dew honey and blended honey the results were inconsistent, reaching 24.6% 50%, 6.3%, respectively. Our results show that analytical methods should be used for correct determination of honey origin. For most of the honeys, the beekeepers' classification was different from the measured electrical conductivity, whose legal limit is one of the criteria for determining the origin of the honey. For blossom honey, incorrect classification was given by el. cond. (39%), F+G (14%), moisture (29%), and by high sucrose content in one case. For honeydew honey, incorrect classification was mainly by low el. cond. (100%). For blended honey, beekeepers did not classify two samples correctly, where high el. cond. and total acidity was detected. Our results also show that there is more monofloral honey in Czech Republic than it was determined by the beekeepers. 6.8% or 23.0% of blossom honey was in compliance with the definition for monofloral honey for upper or lower limit respectively. In this study, the beekeepers supposed 2.6% of monofloral honeys but most of them were actually classified incorrectly. The discrepancy in the declaration of monofloral honeys shows that the classification of the origin of honeys is still problematic. Therefore, new methods or a better characterised distinction for monofloral honeys are needed. On the other hand, further research is needed to identify the environmental, agricultural and behavioural conditions that can lead to the production of monofloral honeys.

Acknowledgments: The project is co-financed by the governments of the Czech Republic, Hungary, Poland, and Slovakia through Visegrad Grants from the

International Visegrad Fund no. 22220064. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe and co-financed by the Applied Research Programme of the Ministry of Agriculture for the 2017–2025, THE LAND, number QK1920344.

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Vztah pokryvu krajiny k pylovému profilu medu
Pollen profile relation to country land cover

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Souhrn
Monitoring půdního pokryvu je v současnosti prováděn automatickými geografickými systémy, které na základě analýzy viditelného a blízkého infračerveného spektra poskytují informace o způsobu využití půdy. V práci je ověřován vztah pylového profilu medu k pokryvu krajiny v regionu Morava, Česká republika. Analyzováno bylo 17 stanovišť, krajinný pokryv byl hodnocen jako 3 km poloměr od stanoviště. Celkem byla vyhodnocena plocha 48 042 Ha v návaznosti na jednotlivá stanoviště. Z toho 57 % zabírala zemědělská půda, 22 % urbanizované území, 21 % lesy a 0,1 % vodní plocha. Výsledky prokázaly silnou korelaci pro některé botanické taxony a typy pokryvu identifikované pomocí CORINE land cover, konkretně *Aruncus* sp., *Hipericum* sp., *Trifolium* sp. (R=0,99, R=0,99, R=0,95) u klasifikace 3 typů a s *Brassica* sp., *Echium* sp., *Rubus* sp. u klasifikace 2 typů (R=0,99, R=0,96, R=0,96) ($p < 0,05$).
Klíčová slova: *melissopalynologie, GIS, pokryv krajiny Corine, CLC*

Abstract
Land cover monitoring is currently carried out by automated geographic systems. These provide information on land use based on the analysis of the visible and near-infrared spectrum. This article examines the relationship between honey pollen profile and land cover in the region of Moravia, Czech Republic. Seventeen hive location were analysed and land cover was assessed as a 3 km radius around the site. In total, an area of 48,042 ha was evaluated in relation to individual hive location. Of this, 57% was agricultural land, 22% urban land, 21% forest and 0.1% water. The results showed a strong correlation for some botanical taxa and cover types identified by CORINE land cover. Specifically, *Aruncus* sp., *Hipericum* sp., *Trifolium* sp., (R=0.99, R=0.99, R=0.95) for type 3 classification and with *Brassica* sp., *Echium* sp., *Rubus* sp. for type 2 classification (R=0.99, R=0.96, R=0.96) ($p < 0.05$).
Key worlds: *melissopalynology, GIS, Corine land cover, CLC*

Úvod
Dálkový průzkum země umožnuje sběr velkého množství dat, které lze interpretovat různými způsoby podle toho jaké družice a jaké detektory, převážně různých formě záření, byly analyzovány. V rámci evropského vesmírného výzkumu, je umožněn přístup k těmto datům, jak v binární podobě, tak v podobě vyhodnocených informací. Pro sledování pokryvu půdy se využívají satelity Sentinel-2 snímající zemský povrh ve viditelném spektru RGB (červená, zelená, modrá), NIR, spektra blízká NIR(Phiri et al., 2020), SWIR a Landsat-8 využívající VNIR a SWIR (využívajících vlnové délky 443, 865, and 2201 nm) (Gorroño et al., 2017). Takto získána satelitní data jsou zpracovány pro vytvoření charakteristiky krajinného pokryvu matematickými modely (Dušek a Popelková, 2017) a jsou volně dostupné jako CORINE land cover (CLC).

Kolonie včely medonosné jsou součástí krajiny a její zdravotní stav a také produkce medu je závislá na nektarových a pylových zdrojích v okolí stanoviště dané včelí kolonie. Nektar představuje zdroj sacharidů pro včelstvo, pyl je zdrojem proteinů (Bryś et al., 2021). Oba tyty zdroje přitom nachází uplatnění v podobě včelích produktů a to ve formě medu a sušených pylových rousek. Blízkost oblastí s intenzivní zemědělskou činností, může být na druhou stranu zdrojem znečistění v podobě pesticidů, které jsou jednou z příčin CCD (náhlý kolaps kolonie včelstva) (VanEngelsdorp et al., 2009).
Cílem práce bylo ověřit v regionu Morava, Česká republika vztah mezi daty získanými s CLC a výsledky melissopalynologické analýzy medu.

Material a metodika

Byly použity data z CLC 2020 získané z Evropské agentury životního prostředí (European Environment Agency's Copernicus Land Monitoring Service). Data byla zpracována v programu QGIS 3.28 (QGIS Development Team, 2023). Kolem každého stanoviště byla vyhodnocována plocha o poloměru 3 km. Vyhodnocení půdního pokryvu bylo provedeno podle klasifikace k CLC a to samostatně pro typ 1 (5 skupin), typ 2 (15 skupin) a typ 3 (44 skupin), viz také tabulka 1. Vyhodnocení bylo jako součet celkové plochy jednotlivých skupin pro jedno stanoviště s následným procentuálním vyjádřením. Medy byly vyšetřeny semiautomatickou analýzou podle Pospiech a kol. (Pospiech et al. 2021). Autentické medy byly odebrány přímo od hobby včelařů a v medech bylo stanoveno relativní zastoupení botanických taxonů.
Statistická analýza byla provedena ve statistickém software Xlstat (Adinsoft, USA) a jako statistická metoda byl použit Pearsanův korelační koeficient na hladině významnosti $p < 0,5$. Korelace byla provedena mezi celkovou plochou hodnocené skupiny a procentuálním zastoupením daného botanického taxonu.

Výsledky a diskuse

Výsledky z CLC lze pro jednotlivá stanoviště klasifikovat do různě podrobných tříd. Nejhrubší klasifikaci (označované jako typ1) zahrnuje 5 skupin, další klasifikace typ 2 15 skupin a nejpodrobnější klasifikace je typ 3 která zahrnuje 44 skupin. Volba jednotlivých typů pro analýzu tedy upravuje celkovou plochu v dané třídě, se kterou je srovnáván pylový profil, na druhou stranu hrubá klasifikace nemusí nutně odpovídat charakteru krajiny. Výsledky pro typ 1 potvrdil statisticky významnou korelaci pro *Campanula sp* R=0,52 v urbanizovaných územích a pro *Thymus* sp. R=0,55 ve skupině zemědělské plochy. Ve skupině lesy a polopřírodní oblasti byla potvrzena pouze negativní korelace pro *Salix* sp. R=-0,634 a pro *Helianthus anus* R=-0,586. Toto zjištění není překvapivé, protože tato klasifikace zahrnuje oblasti, které zahrnují různě využívanou plochu a tím pádem dochází k velkému rozptylu také v množství a přítomnosti pylových zrn pro jednotlivé klasifikační třídy. Souhrn klasifikačních typů je uveden v tabulce 1 spolu s procentuálním zastoupeným v analyzovaných stanovištích.

Annex 2: Vztah pokryvu krajiny k pylovému profilu medu
(Pollen profile relation to country land cover)

Tabulka 1: Klasifikace půdního pokryvu s CLC 2020 s procentuálním zastoupeným půdního pokryvu (klasifikační skupiny).

Typ 1	Typ 2	Typ 3
Urbanizovaná území (22 %)	Obytné plochy (15 %)	Městská souvislá zástavba (0,1 %)
		Městská nesouvislá zástavba (15 %)
	Průmyslové a obchodní zóny, komunikační síť (5 %)	Průmyslové nebo obchodní zóny (4 %)
		Silniční a železniční síť a přilehlé prostory (1 %)
		Přístavní zóny
		Letiště
	Doly, skládky a staveniště (0,4 %)	Těžba hornin (0.4 %)
		Skládky
		Staveniště
	Plochy umělé, nezemědělské zeleně (1 %)	Plochy městské zeleně (0,1 %)
		Zařízení pro sport a rekreaci (1 %)
Zemědělské plochy (57 %)	Orná půda (30 %)	Orná půda mimo zavlažovaných ploch (30 %)
		Plochy stále zavlažované
		Rýžová pole
	Stálé kultury (2 %)	Vinice (1 %)
		Ovocné sady a keře (1 %)
		Olivové porosty
	Pastviny (8 %)	Pastviny (8 %)
	Různorodé zemědělské plochy (18%)	Roční kultury přidané ke stálým kulturám
		Komplexní systémy kultur a parcel (3 %)
		Převážně zemědělská území s příměsí přirozené vegetace(14 %)
		Území zemědělskolesnická
Lesy a polopřírodní oblasti (21 %)	Lesy (20 %)	Listnaté lesy (5 %)
		Jehličnaté lesy (4 %)
		Smíšené lesy (11 %)
	Plochy s křovinnou a travnatou vegetací (1 %)	Přírodní pastviny
		Slatiny a vřesoviště, křovinaté formace
		Sklerofylní vegetace
		Přechodová stadia lesa a křoviny (1 %)
	Otevřené plochy s malým zastoupením vegetace nebo bez vegetace	Pláže, duny, písky
		Holé skály
		Oblasti s řídkou vegetací
		Vypálené oblasti
		Ledovce a věčný sníh
Humidní území	Vnitrozemská humidní území	Vnitrozemské bažiny
		Rašeliniště
	Přímořská humidní území	Přímořské bažiny
		Slané bažiny
		Přibřežní zóny
Vodní plochy (0,1 %)	Pevninské vody (0,1 %)	Vodní toky a cesty
		Vodní plochy (0,1 %)
	Mořské vody	Laguny
		Ústí řek
		Moře a oceány

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Annex 2: Vztah pokryvu krajiny k pylovému profilu medu
(Pollen profile relation to country land cover)

Pro klasifikační třídu typ 2 je už rozdělení více podrobné a z naměřených dat lze vidět, že podrobnější kategorizace má větší vztah k botanickým taxonům, které byli potvrzené v medech pro stanoviště s daným typem půdního pokryvu. V sledované blízkosti stanovišť bylo zastoupeno jen sedm skupin. Největší zastoupení přitom měla orná půda (30 %, a nejmenší 0,1 % pevninské vody). Shrnutí výsledků s potvrzenou korelací je uvedeno v tabulce 2, kde jsou uvedeny pouze hodnoty statisticky významné ($p < 0,5$).
Výsledky analýzy třídy typu 2 pro klasifikační skupinu lesy, a různé zemědělské plochy potvrdila pouze negativní korelaci s taxony *Salix* sp., a *Lotus* sp. ($p < 0,5$). Výsledek ukazuje, že tyto taxony se nachází v málo četném zastoupení pro danou skupinu zemědělského pokryvu půdy. Důvodem je nízký výskyt těchto taxonů v daných biomech. Kdy vrba je typická pro blízkosti vodních toků (Çelemli, 2012) a Lotus sp. pro oblasti s nízkou zemědělskou činností, respektive je to typický taxon pro pastviny (Winkler et al., 2022). Pro oblasti s městkou zástavbou (obytné plochy) byla potvrzena pozitivní korelace s výskytem taxonu *Aesculus* sp., který zahrnuje oblíbený strom parkových výsadeb Pakaštan koňský (Kopačka a Zemek, 2023), který je květem atraktivní nejen pro obyvatele, ale také pro včely a slouží jako zdroj pylu a nektaru ((Demianowicz, 1964)). Podobné využití mají zelené plochy nevyužívané pro zemědělské účely (městská zeleň a sportoviště), kde byla potvrzena vysoká pozitivní korelace s taxony *Echium* spi, *Rubus* sp. a *Trifolium* sp. ($p < 0,05$), tedy taxony vyskytujícími se v přirozeně zelené krajině nebo na pastvinách (*Trifolium* sp.).

Tabulka 2: Vztah botanických taxonů ke klasifikační třídě typu 2 dle CLC

	Lesy	Obytné plochy	Orná půda	Pastviny	Plochy umělé, nezemědělské zeleně	Průmyslové a obchodní zóny	Různorodé zemědělské plochy	Stálé kultury
Aesculus sp.		0,6						
Betula sp.				0,92				
Brasica sp.							-0,53	0,99
Campanula sp						0,87		
Echium sp.					0,96			
Hypericum sp.				0,92				
Lotus sp.			0,61	0,98			-0,6	
Phacelia sp.				0,91				
Rhamnus sp.				0,92				
Rubus sp.					0,96			
Salix, Salicaceae	-0,54		0,48					
Trifolium sp.					0,9			

Překvapivá je pozitivní korelace v oblastech s průmyslovým využitím, kde byl potvrzen pyl taxonů *Campanula* sp. a také negativní korelace u taxonu *Brassica* sp., která je v ČR zastoupena převážně ozimou řepkou (Pospiech et al., 2021). Tento vztah vysvětlujeme s ohledem na negativní korelace v třídě typu 3 dle CLC ($p > 0,5$), která blíže specifikuje charakteristiku této skupiny na převážně zemědělská území s příměsí přirozené vegetace. Jsou to tedy oblasti nevyužívající ornou půdou pouze intenzivní zemědělskou činností, ale podíl přirozené vegetace poskytuje také další zdroje snůšky, což vede k poklesu v obsahu pylu řepky v medech v těchto oblastech. Půdy s nejvyšším stupněm zemědělského obdělávání (orné půdy) potvrdily pozitivní korelaci k pylu taxonu *Lotus* sp. a *Salix* sp. ($p > 0,5$). A nejvíce taxonů s pozitivní korelací k půdnímu pokryvu byly potvrzeny u taxonů *Betula* sp., *Brassica* sp., *Hypericum* sp., *Lotus* sp., *Phacelia* sp. a *Rhamnus* sp. Tento výsledek potvrzuje, že pastviny jsou pestré na původní botanické taxony, které jsou pro včely tradičně dobrým zdrojem jak pylu, tak nektaru nezbytného pro rozvoj včelí kolonie a také produkci včelích produktů. Přítomnost *Lotus* sp. na pastvinách byl potvrzen také na vysočině (Winkler et al., 2022). Ve srovnání s klasifikací podle 2 typu nebyla u taxonu *Brassica* sp. potvrzena statisticky významná korelace, i když korelace taxonu k půdnímu pokryvu byla vysoká ($R = 0,87$).

Klasifikační třída typ 3 má nejpodrobnější klasifikaci, což vedlo také k nejčastějšímu potvrzení závislosti v botanických taxonech prokázaných v medu s daným typem lokality klasifikovaného podle CLC. Pro tento typ byla nejvíce zastoupená orná půda mimo zavlažovaných ploch (30 %), nejméně byly, jako u předešlého typu, zastoupeny vodní plochy (0,1 %).

U klasifikačního typu 3 byla potvrzena závislost s půdním pokryvem největší z analyzovaných typů (Tabulka 3). Přičemž výsledek klasifikace je většinou v souladu s výsledky pro kategorizaci 2 typu, jak bylo popsáno výše. Lesní porost je pro tuto klasifikaci rozdělen na listnaté lesy, smíšené lesy a přechodová stadia lesa a křoviny a pro jednotlivé skupiny. Ve srovnání s předešlými klasifikacemi bylo potvrzeno více botanických taxonů korelujích s půdním pokryvem. Potvrzeny byly *Aruncus* sp., *Phagophyrum* sp., *Trifolium* sp. a *Lotus* sp. Přítomnost *Lotus sp.* v přechodových oblastech lesa lze vysvětlit vysokou adaptovatelností tohoto taxonu k různým typům půdy (Zedníková et al., 2023).

Překvapivým je obsah druhu pohanky ve skupině listnaté lesy. V ČR se vyskytují dva druhy Pohanka obecná a tatarská, oba druhy jsou neofyty a od 19 století jejich výskyt byl potvrzen i v krajinných biotypech (Mabberley, 2023) a bylo potvrzeno jejích osídlování v neudržovaných loukách (Hadrava et al., 2022). Pro ověření tohoto vztahu by bylo vhodné provést bližší botanický průzkum daných lokalit a vyvrátit nepřesné určení daného taxonu podrobnější klasifikací, jestliže pyl nepochází z jiné pro ČR původní byliny čeledě rdesnovitých. S ohledem na vysokou atraktivitu pohanky se ale může jednat také o preferovaný botanický taxon (Tschumi et al., 2015; Hadrava et al., 2022). Městská nesouvislá zástavba, průmyslové nebo obchodní zóny a zařízení pro sport a rekreaci kopírují výsledky z klasifikace, jak byla u 2 typu. Potvrzena byla pozitivní korelace s taxony *Aesculus* sp., *Campanula* sp. a *Trifolium* sp. (Tabulka 3).

Ve srovnání s předchozími typy klasifikace dle CLC, bylo pro zemědělské půdy potvrzeno v tomto typu nejvíce vzájemných vztahů, celkem bylo potvrzeno 11 taxonů ve vztahu k půdnímu pokryvu. Kategorie ovocné sady a keře poskytuje překvapivé zjištění, že tato oblast koreluje s obsahem pylu lípy v medech s ohledem na rozsahu této kategorie v okolí stanoviště včelstva. Výsledek nebyl očekáván a pro potvrzení nebo vyvrácení je vhodné zahrnou do analýzy další takto klasifikované oblasti. Nejvíce taxonů pozitivně korelujících k půdnímu pokryvu bylo pro pastviny *Betula* sp., *Brassica* sp., *Hypericum* sp., *Losus* sp., *Phacelia* sp., *Rhamns* sp. a dále pro komplexní systémy kultur a parcel kde byly zastoupeny taxony *Aruncus* sp., *Helianthus* sp., *Hypericum* sp., *Lythrum* sp. a *Salix* sp. Toto zjištění je v souladu s obecným tvrzením, že pro rozvoj včelstva je důležitý pestrý zdroj pylové a nektarové snůšky, který podle našich výsledků jsou schopny dosáhnout právě půdní pokryvy, které mají pestřejší zastoupení taxonů podílejících se na snůšce včelstva. I když podle literárních zdrojů dochází i u trvalých travních porostů k postupnému ubývaní botanických druhů (Harásek et al., 2023).

Tabulka 3: Vztah botanických taxonů ke klasifikační třídě typu3 dle CLC

	Komplexní systémy kultur a parcel	Listnaté lesy	Městská nesouvislá zástavba	Orná půda mimo zavlažovaných ploch	Ovocné sady a keře	Pastviny	Průmyslové nebo obchodní zóny	Přechodová stadia lesa a křoviny	Smíšené lesy	Zařízení pro sport a rekreaci
Aesculus sp.			0,59							
Aruncus *sp.*		0,83								
Aruncus *sp.*	0,99									
Betula sp.						0,92				
Brasica sp.						0,87				
Campanula sp.							0,86			
Helianthus sp.	0,86									
Hypericum sp.	0,99					0,92				
Lotus sp.				0,59		0,91		0,82		
Lythrum sp.	0,93									
Phacelia sp.						0,91				
Phagopyrum sp.		0,80								
Rhamnus sp.						0,92				
Salix, Salicaceae	0,77									
Tilia *sp.*					1,00					
Trifolium sp.									0,69	0,95

Závěr

Byl potvrzen vztah mezi výskytem pylových taxonů v medu a mezi některými typy půdního pokryvu ČR mapovaného pomocí družicového systému a vyhodnoceného evropským systémem CORINE Land cover. Nejčastěji byla potvrzena korelace pylových taxonů krajinného pokryvu s podílem původních krajinných prvků a městské zeleně. Nejvyšší stupeň korelace byl pro taxony *Aruncus* sp., *Hipericum* sp., *Trifolium* sp., (R=0,99, R=0,99, R=0,95) u klasifikace 3 typu a s *Brassica* sp., *Echium* sp., *Rubus* sp. u klasifikace 2 typu (R=0,99, R=0,96, R=0,96) (p < 0,05). Klasifikace 1 typu potvrdila pouze slabou korelaci a není pro tento účel srovnání vhodným stupněm klasifikace. Pro některé druhy (*Brassica* sp., *Lotus* sp., *Salix* sp.) byl naopak potvrzen negativní vztah v některých krajinných typech.

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Poděkování: Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projekty: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

Visegrad Fund

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VLIV PŮDNÍHO POKRYVU NA ZÁKLADNÍ PARAMETRY MEDŮ INFLUENCE OF LAND COVER ON THE HONEY PARAMETERS

Matej Pospiech, Simona Ljasovská, Marie Bartlová, Helena Čížková, Vojtěch Kružík, Dalibor Titěra, Barbara Prus, Bohuslava Tremlová

Abstract: The geographical origin of honey can be identified through physic-chemical composition or pollen analysis. This is based on the assumption that the natural resources are unique to the region. The aim of this research was to investigate the potential correlation between physicochemical parameters, pollen profile, and land cover identified through remote sensing. Moisture, acidity, HMF, diastase, conductivity, carbohydrates, and the presence of pollen taxa were analysed using melissopalynology. Statistical significance ($p<0.05$) was observed in the differences between the measured parameters and land cover. The variability was higher for pollen taxa compared to physicochemical parameters. The findings indicate that no single variable could accurately distinguish all types of land cover. Utilizing a combination of multiple variables and advanced statistical methods will be necessary for differentiation.
Keywords: melissopalynology, CORINE Land Cover, geographic information system, prediction

ÚVOD

Med je oblíbeným sladidlem s dlouhou tradicí mezi konzumenty. Tradice konzumace medu sahá hloubko do minulosti a představuje první z dostupných zdrojů cukrů. Tradice, obliba a vyšší cena medu vede často k falšování tohoto produktu. Falšování může být prováděno různými způsoby. Jedním z nich je záměna geografického původu medu. Pro průkaz geografického původu medu existuje více metod, které jsou založeny na určení botanického původu (Kaškonienė et al., 2010), izotopového profilu (Kawashima et al., 2018), magnetické rezonance (Zheng et al., 2016) nebo obsahu látek, jako jsou např. minerální látky, polyfenoly nebo pyl (Ohmenhaeuser et al., 2013; Karabagias et al., 2014; Pasquini et al., 2014). Důvodem velkého spektra metod využívaných pro geografickou identifikaci medu je komplikovanost tohoto průkazu. Definovat geografický původ je sice snadné, protože je dána stanovištěm, ale definovat charakteristiku medu specifickou pro konkrétní lokality je obtížné. Na charakteristiku medu, která je daná složením medu má vliv mnoho faktorů, zejména zdroj snůšky, klimatické podmínky, botanické zastoupení a pro izotopové metody a magnetickou rezonanci také množství srážek (Kawashima et al., 2018). Na všechny tyto činitele má vliv využití půdy v daných lokalitách, které je významně ovlivněno antropogenními faktory. Za klíčové lze považovat zavlažování, selekci konkrétních botanických druhů, výstavbu budov a podobně. Lidmi upravená krajina poskytuje tudíž specifický zdroj pastvy, ale i na samotnou pastvu má antropogenní činnost vliv. Cílem práce je určit vliv půdního pokryvu (využití půdy) na základní složení medu.

MATERIÁL A METODIKA

Ve studii bylo analyzováno 32 vzorků medu, které byly získány od hobby včelařů z různých lokalit České republiky. Medy byly analyzovány podle doporučených postupů mezinárodní medové komise (Bogdanov, 2009). Analyzovány byly parametry: obsah vody (%), kyselost (meq.kg^{-1}), hydroxymethyl furfural (HMF, mg.kg^{-1}), aktivita diastázy (DN), vodivost (mS.m^{-1}), barva medu (mm pfund), sacharóza, fruktóza, glukóza, turanóza, maltóza, trehalóza, melezitóza (%). Pylová analýza byla provedena podle standardního postupu

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(Pospiech et al., 2021). Navážka vzorků medu byla 5 gramů. Vzorky byly filtrovány (velikost pórů 5 µm) (MERK, CZE) a po vysušení byly vzorky zality syntetickou pryskyřicí Solakryl (VWR, CZE). Snímání náhodných zorných polí bylo při dvě stě násobném zvětšení. Byl použit in-home zobrazovací systém zahrnující mikroskop Eclipse (Nikon, JPN), kameru (Imagine source, GER) a snímací software (Laboratory imagine, CZE).

Data dálkového průzkumu země byla získána ze systému CORINE Land Cover (CLC) v rámci volné licence. Zpracování dat proběhlo za pomoci mapového softwaru QGIS (A Free and Open Source Geographic Information System, 3.28.15 LTR). Pro každé včelí stanoviště, od kterého byl odebrán vzorek medu, byla vypočtena plocha krajinného pokryvu stanovena dle metodiky CLC. Analyzovaná plocha byla 3 km v poloměru. Tři kilometry byly zvoleny jako průměrná letová vzdálenost včel.

Data byla srovnána pomocí statistického software XLSTAT (Addinsoft, USA). Byl použit test ANOVA s mnohonásobným porovnáním Tukey HSD na hladině významnosti $p < 0{,}05$.

VÝSLEDKY A DISKUSE

V této práci bylo zastoupeno 14 typů půdního pokryvu. Ne všechny byly ve stejném procentuálním zastoupení, z toho důvodu byla u všech statistických testů použita váhová korekce, která byla definována jako celková plocha půdního pokryvu pro dané stanoviště. Konkrétně byly hodnoceny typy půdního pokryvu, které jsou uvedeny s použitou zkratkou a procentuálním podílem v hodnocené rozloze. Listnaté lesy (Lis, 5,22 %), komplexní systémy kultur a parcel (Kom, 3,35 %), jehličnaté lesy (Jeh, 4,34 %), městská nesouvislá zástavba (Měs, 14,93), ovocné sady a keře (Ovo, 0,86 %), průmyslové nebo obchodní zóny (Prů, 4,38), převážně zemědělská území s příměsí přirozené vegetace (Pře, 14,2 %), těžba hornin (Tež, 0,41), smíšené lesy (Smí, 10,52 %), orná půda mimo zavlažovaných ploch (Orn, 29,98), pastviny (Pas, 8,03), silniční a železniční síť a přilehlé prostory (Sil, 0,93), zařízení pro sport a rekreaci (0,83) a vinice (Vin, 0,86).

Půdní typy byly srovnány s fyzikálně-chemickými parametry (**Tabulka 1**) a pylovým profilem medu (**Tabulka 2**) s hodnocených stanovišť.

Z uvedených výsledků je zřejmé, že obsah vody, kyselost, HMF, aktivita diastázy neměli souvislost s typem půdního pokryvu. Tento výsledek není překvapivý, protože jsou to parametry, které souvisí zejména manipulací s medem. Aktivita diastázy může být také nízká u některých jednodruhových medů (Persano Oddo & Piro, 2004) a naopak obsah HMF může být vysoký zejména u medů z tropických oblastí (Juan-Borrás et al., 2014). Ze sacharidů sacharóza, fruktóza, turanóza, maltóza, melecitóza byla bez zřetelné souvislosti k půdnímu pokryvu. V případě sacharózy, turanózy, maltózy a melecitózy to bylo očekávané zejména z důvodu, že obsah těchto sacharidů je nízký a neliší se ani v průběhu let (Čížková et al., 2022). Naopak zajímavým zjištěním jsou rozdíly mezi jednotlivými typy půdního pokryvu u glukózy a trehalózy. Nejvyšší hodnota glukózy byla zaznamenána u lokalit s výskytem porostů jehličnanů (36,01 %) a tato hodnota se statistiky lišila od ostatních typů půdního pokryvu ($p<0{,}05$). U trehalózy byla statisticky nejvyšší hodnota u lokalit s těžební činností (1,11 %) a nejnižší u jehličnanů (0,18 %). Toto zjištění je v rozporu se španělskou studií (Bentabol Manzanares et al., 2011), kde byl obsah trehalózy vyšší u medovicových medů (1,89 %) ve srovnání s květovými (1,67 %). V našem případě byl obsah trehalózy nižší (1,11 %) než by odpovídalo medovicovému medu (**Tabulka 1**). Trehalóza však může být také v květových medech, kdy se její obsah pohybuje od 1,5 do 2 % (Bentabol Manzanares et al., 2014).

Tabulka 1 Srovnání fyzikálně chemických parametrů medu

Půdní pokryv	Obsah vody (%)	Kyselost [meq/kg]	HMF [mg/kg]	DN) [stupňů]	Vodivost [mS/m]	Sacharóza (%)	Fruktóza (%)	Glukóza (%)	Turanóza (%)	Maltóza (%)	Trehalóza (%)	Melezitóza (%)	medu [mm
Orn	17,29^{a}	20,83^{a}	3,03 ^{a}	24,38^{a}	45,48^{bcd}	0,93^{a}	37,32^{a}	32,27^{ab}	1,96^{a}	3,73^{a}	0,55^{abc}	0,42^{a}	44,08^{a}
Měs	16,97^{a}	19,75^{a}	2,2 ^{a}	26,12^{a}	57,37^{abcd}	0,78^{a}	37,6^{a}	31,88^{ab}	2,15^{a}	4,02^{a}	0,68^{abc}	0,34^{a}	46,64^{a}
Pře	16,48^{a}	22,16^{a}	3,11 ^{a}	23,12^{a}	68,34^{abc}	0,69^{a}	36,615^{a}	30,86^{b}	2,27^{a}	3,96^{a}	0,89^{ab}	0,65^{a}	39,84^{a}
Smí	16,71^{a}	22,18^{a}	1,85^{a}	23,25^{a}	67,5^{abcd}	0,41^{a}	36,75^{a}	30,84^{b}	2,29^{a}	4,01^{a}	0,85^{abc}	0,71^{a}	43,99^{a}
Lis	16,38^{a}	**28,5^{a}**	4,55^{a}	23,56^{a}	60,28^{cd}	0,31^{a}	36,96^{a}	30,44^{b}	**2,54^{a}**	4,06^{a}	0,77^{abc}	**0,80^{a}**	**56,83^{a}**
Pas	15,89^{a}	20,94^{a}	**10,19^{a}**	19,49^{a}	67,75^{abcd}	0,45^{a}	36,4^{a}	31,67^{ab}	2,35^{a}	3,44^{a}	**0,923^{ab}**	0,72^{a}	38,15^{a}
Kom	**17,69^{a}**	22,61^{a}	1,36^{a}	24,93^{a}	42,411^{bcd}	1,12^{a}	37,92^{a}	31,18^{b}	1,73^{a}	3,47^{a}	0,56^{abc}	0,63^{a}	40,24^{a}
Vin	17,72^{a}	26,97^{a}	1,21^{a}	25,95^{a}	33,48 ^{d}	**2,22^{a}**	37,91^{a}	30,54^{b}	1,49^{a}	3,21^{a}	0,43^{bc}	0,55^{a}	39,53^{a}
Prů	17,0^{a}	21,21^{a}	1,16^{a}	26,36^{a}	67,36^{abcd}	0,49^{a}	37,92^{a}	32,00^{ab}	1,99^{a}	3,96^{a}	0,77^{abc}	0,19^{a}	41,12^{a}
Ovo	16,65^{a}	27,71^{a}	2,46^{a}	23,56^{a}	58,04^{abcd}	0,79^{a}	37,36^{a}	31,16^{b}	1,80^{a}	3,61^{a}	0,69^{abc}	0,40^{a}	36,74^{a}
Sil	16,73^{a}	22,43^{a}	0,83^{a}	**27,00^{a}**	73,97^{ab}	0,42^{a}	38,05^{a}	31,74^{ab}	2,06^{a}	4,10^{a}	0,78^{abc}	0,17^{a}	43,33^{a}
Jeh	17,1^{a}	13,63^{a}	5,15^{a}	14,7^{a}	35,26^{cd}	0,16^{a}	**38,13^{a}**	**36,01^{a}**	1,77^{a}	3,9^{a}	**0,18^{c}**	0,26^{a}	46,83^{a}
Zař	16,04^{a}	17,86^{a}	2,12^{a}	21,07^{a}	69,00^{abc}	0,22^{a}	36,53^{a}	30,95^{b}	2,53^{a}	**4,78^{a}**	0,88^{ab}	1,11^{a}	36,74^{a}
Těž	15,83^{a}	19,08^{a}	1,44^{a}	22,80^{a}	**82,20^{a}**	0,21^{a}	36,1^{a}	30,44^{b}	2,42^{a}	4,47^{a}	**1,11^{a}**	1,15^{a}	33,17^{a}

Rozdílný horní index indikuje statisticky významné rozdíly ve sloupcích.

Tabulka 2 Srovnání pylového profilu medu s typem půdního pokryvu

Půdní pokryv	Brasica sp	Robinia sp	Salix, Salicaceae	Bellis sp.	Helianthus sp.	Umbelliferae sp.	Amaryllidaceae	Campanula sp	Echium sp.	Thymus sp.	Hypericum sp.
Orn	29,12^{ab}	2,23^{b}	1,38^{abc}	0,13^{b}	0,49^{bc}	6,25^{ab}	0,2^{b}	0,32^{ab}	0,17^{bc}	0,64^{ab}	0,52^{b}
Měs	30,08^{ab}	0,25^{b}	0,85^{bc}	0,12^{b}	0,4^{c}	5,69^{ab}	0,06^{b}	0,35^{ab}	0,13^{bcd}	0,34^{ab}	0,46^{b}
Pře	9,99^{b}	2,59^{b}	0,81^{bc}	0,40^{a}	0,09^{c}	4,89^{ab}	0,3^{b}	0,59^{ab}	0,16^{bc}	0,65^{ab}	0,06^{b}
Smí	8,92^{b}	2,72^{b}	0,68^{bc}	0,33^{a}	0,00^{c}	5,24^{ab}	0,31^{b}	0,46^{ab}	0,14^{bcd}	0,48^{ab}	0,11^{b}
Lis	5,19^{b}	0,28^{b}	0,13^{c}	0,05^{b}	0,00^{c}	4,57^{ab}	0,02^{b}	0,17^{b}	0,09^{bcd}	0,01^{b}	0,45^{b}
Pas	7,12^{b}	2,43^{b}	0,54^{bc}	0,35^{a}	0,00^{c}	4,23^{ab}	0,15^{b}	0,74^{ab}	0,14^{bcd}	0,7^{ab}	0,35^{b}
Kom	23,92^{ab}	0,00^{b}	3,32^{abc}	0,03^{b}	2,22^{ab}	4,06^{ab}	0,00^{b}	0,00^{b}	0,53^{a}	1,29^{ab}	**3,16^{a}**
Vin	24,91^{ab}	0,00^{b}	**4,83^{a}**	0,00^{b}	**3,12^{a}**	4,99^{ab}	0,00^{b}	0,00^{b}	**0,74^{a}**	**1,95^{a}**	4,0^{a}
Prů	32,07^{ab}	0,00^{b}	0,62^{bc}	0,01^{b}	0,05^{c}	4,4^{ab}	0,00^{b}	1,02^{ab}	0,05^{cd}	0,05^{ab}	0,00^{b}
Ovo	21,14^{ab}	**11,36^{a}**	4,07^{ab}	**0,71^{a}**	0,14^{c}	**9,14^{a}**	**1,43^{a}**	**1,86^{a}**	0,07^{bcd}	1,5^{ab}	0,00^{b}
Sil	33,33^{ab}	0,00^{b}	0,67^{bc}	0,00 b	0,00^{c}	4,67^{ab}	0,00^{b}	1,33^{ab}	0,00^{cd}	0,00^{b}	0,00^{b}
Jeh	**56,71^{a}**	0,00^{b}	0,11^{c}	0,11^{b}	0,00^{c}	4,79^{ab}	0,06^{b}	0,11^{b}	0,00^{d}	0,06^{ab}	0,11^{b}
Zař	7,53^{b}	0,00^{b}	0,00^{c}	0,15^{ab}	0,00^{c}	1,99^{ab}	0,00^{b}	0,00^{b}	0,35^{abc}	0,00^{b}	0,00^{b}
Těž	0,00^{b}	0,00^{b}	0,00^{c}	0,22^{ab}	0,00^{c}	**0,72^{b}**	0,00^{b}	0,00^{b}	0,50^{ab}	0,00^{b}	0,00^{b}

Rozdílný horní index indikuje statisticky významné rozdíly ve sloupcích.

Kromě základních fyzikálně-chemických parametrů medu byly srovnány také rozdíly procentuálního zastoupení botanických taxonů v oblastech s různým zastoupením půdního pokryvu. Kromě taxonů uvedených v tabulce 2 byly potvrzeny taktéž taxony rodů Artemisia, Alnus, Rubus, Betula, Acer, Castanea, Trifolium, Tilia, Phacelia, Rhamnus, Vicia,

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Taraxacum, Aesculus, Lythrum, Phagopyrum, Lotus, Aruncus a zástupci blíže neurčených čeledí *Balsaminaceae, Apiaceae, Rosaceae*. Mezi těmito taxony však nebyl potvrzen statisticky významný rozdíl (p>0,05). Mezi taxony uvedenými v tabulce 2 byly zaznamenány statistické rozdíly (p<0,05) což vypovídá o vlivu půdního pokryvu k zastoupeným taxonům na daných lokalitách. Ne vždy je ale vztah předvídatelný. Příkladem je vysoký výskyt řepky (56 %) v oblastech s vysokým zastoupením jehličnatých lesů. Na druhou stranu výskyt květin a suchomilných rostlin (rody: Helianthus, Echium, Thymus) v oblastech s výskytem vinic je očekávaný. Výskyt akátu (11,36 %) v oblastech s podílem ovocných sadů lze vysvětlit sběrem akátu po vyčerpání rezerv včelstev, které vznikly spotřebování zásob z ovocných stromů. Určitou roli nejspíše hraje také daná oblast, kdy ovocné sady jsou v oblastech s menším podílem intenzivního zemědělství, a tedy menším podílem pylu řepky, která předchází akátu. Pyl vrby je typický pro jarní medy a spíše jihovýchodní oblasti Evropy, tedy oblasti s teplým klimatem (Persano Oddo et al., 2004). Vysoký podíl vrby (3,12 %) v oblastech s vinicemi lze zdůvodnit specifitou daných regionů, kdy vinice jsou spíše v teplejší oblastech, a tedy včely jsou schopny využít také tento poměrně raný zdroj potravy.

U pylů s větší frekvencí výskytu byly potvrzeny statistické rozdíly mezi některými skupinami půdního pokryvu. Toto zjištění je v souladu s naším dřívějším výzkumem, kdy byly potvrzeny korelace mezi jednotlivými pylovými taxony a plochou půdního pokryvu na jednotlivých stanovištích (Pospiech et al., 2023). Závislost mezi pylovými taxony a fyzikálně-chemickými parametry medu potvrdili také další autoři (Bertoncelj et al., 2011; Karabagias et al., 2014; Bodó et al., 2020). Na vyhodnocení více faktorů podobně jako je prezentováno v této studii je vhodné použít metody vyšší statistiky. Pro med byly úspěšně aplikovány metody váženého k-nejbližšího souseda, penalizovaná diskriminační analýza, mnohodimenzionální diskriminační analýza, smršťovací diskriminační analýza, metoda nejbližších centroidů, metoda nejmenších čtverců a také metody náhodných lineárních stromů (Mateo et al., 2021).

ZÁVĚR

Vliv půdního pokryvu se projevuje na fyzikálně-chemických vlastnostech medu a na jeho pylovém profilu. Z výsledků analýzy však nevyplynul specifický fyzikálně-chemický parametr nebo botanický taxon, který by byl typický pro půdní pokryv. Avšak toto zjištění je však v souladu s očekáváními a pro lepší klasifikaci je vhodnější použít některé z modelů vyšší statistiky. Nalezení konkrétního modelu pro klasifikaci bude předmětem dalšího výzkumu.

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Poděkování: Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projekty: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

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HYGIENA ALIMENTORUM XLIV 15. – 17. MÁJ, 2024

VLIV MINERÁLNÍHO SLOŽENÍ PŮDY NA VLASTNOSTI MEDU

THE EFFECT OF SOIL MINERAL COMPOSITION ON HONEY PROPERTIES

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ABSTRACT

Honey is a food of variable composition which is affected by various factors. One of the factors which may affect its composition is the soil type of the area where the honey comes from. The study tested the relationship between the mineral composition of 31 samples of authentic honey from the Czech Republic and data obtained from soil probes within the range of the bee habitat of the hive location (3 km). Both positive and negative correlations were confirmed between the compared parameters.

Key words: soil type, *Apis melifera*, calcium, potassium

ÚVOD

Med se skládá především z fruktózy, glukózy, vody, bílkovin, volných aminokyselin, minerálů, enzymů a vitamínů. Složení medu je variabilní a závisí především na květovém zdroji, geografickém původu, sezónních a environmentálních faktorech a metodách zpracování (Kek et al., 2017). Minerální látky se do medu dostávají transportem přes rostliny produkující nektar a jsou v medu stabilní po dlouhou dobu (Pohl, 2009; Chua et al., 2012).

Geografický původ medu souvisí nejenom s botanickými taxony charakteristickými pro danou oblast, ale také s typem půd, které se v dané oblasti vyskytují. Med je potravina, která je produkována bez přímého vlivu člověka na složení, proto by obsah minerálů v medu mohl odrážet obsah minerálů v půdě a v rostlinách v dané oblasti původu medu. Z tohoto důvodu se minerální profil medů používá na prokázání geografického původu medu. Důvodem je snadné stanovení celého profilu minerálních látek a snadná mineralizace vzorku (Chudzinska and Baralkiewicz, 2010).

Existují výzkumy, ve kterých autoři provedli klasifikaci medů podle obsahu minerálních látek. Tuzen et al. (2007) ve své studii sledovali obsah Cd, Pb, Fe, Mn, Cu, Ni, Cr, Zn, Al a Se

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v medu různého botanického původu z Turecka. Jejich výsledky prokázaly korelace s botanickým a geografickým původem medu.

Cílem této práce bylo ověřit vztah mezi minerálním složením medu a složením půdy ve snůškové vzdálenosti jednotlivých stanovišť.

MATERIÁL A METODIKA

K hodnocení bylo použito 31 autentických vzorků medů z České republiky získaných od včelařů. Minerální profil medů byl vyšetřen atomovým absorpčním spektrometrem ICP-MS 7900 (Agilent, USA) podle normativního postupu STN EN 15763, UNI EN 13805, UNI EN 13804. Analyzovány byly minerální látky: B, Na, Mg, Al, K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Cd, As. Mineralizace vzorků medu byla provedena mikrovlnným mineralizátorem D – 72800 (Berghof products, GER).

Charakteristika půdního profilu byla získána z aplikace "Komplexní průzkum půd" (KPP), což byl první moderní soustavný průzkum půd na území ČSSR, který proběhl v letech 1961–1970. Aplikace zobrazuje hlavní výstupy KPP převedené do digitální podoby. Pro hodnocení byla použita data získané ze sond v doletové vzdálenosti stanovišť (3 km), ze kterých byly získány vzorky medu.

VÝSLEDKY A DISKUZE

Vztah mezi minerálním složením medu a půdy byl ověřen na základě korelace mezi hodnoty získanými z analýzy medu a z datových podkladů monitoringu půdního profilu v České republice. Výsledky jsou shrnuty v tabulce č. 1. Intenzita zelené barvy indikuje sílu vztahu těchto hodnot.

Jak je z tabulky č. 1 zřejmé, byla potvrzena pozitivní i negativní korelace mezi srovnávanými parametry. Překvapivý je výsledek obsahu Ca v medu, který nekoreluje s množstvím Ca v půdě (R=-0,18, $CaCO_3$). Neočekávaným výsledkem je také nepotvrzení vztahu obsahu K v půdě a K v medu (R=0,07, K_2O). Tento výsledek neodpovídá studii Jovetić et al. (2017), která prokázala negativní korelaci obsahu Ca a K v medu a půdě. Vliv na složení medu má spoustu faktorů, které jsou ovlivněny využitím půdy v daných lokalitách a také antropogenními faktory, které zřejmě natolik ovlivnily minerální složení medu a tím byla ovlivněna korelace mezi minerálním složením medu a půdy (Pospiech et al., 2024).

Tabulka č. 1, Korelace mezi minerálním složením medu a vybranými analytickými hodnotami půdy

Minerální látky	Org. uhlík v % (C_t)	Humus v % (C_t 1,724)	$CaCO_3$	pH akt. (H_2O)	pH vým. (KCL)	Titrační acidita mval/100 g	H^{+1}	S mval/100g	T mval/100g	V %	P_2O_5	K_2O
B	0,04	0,05	0,15	0,20	0,29	-0,27	-0,13	0,01	-0,11	0,06	0,14	0,12
Na	-0,15	-0,15	-0,25	0,05	-0,19	0,07	0,06	0,22	-0,10	0,03	-0,15	-0,07
Mg	**0,72**	**0,72**	-0,22	0,09	-0,19	0,26	**0,63**	-0,11	0,02	-0,26	0,05	0,17
Al	0,01	0,01	-0,10	0,11	0,05	-0,04	-0,09	0,11	0,23	0,13	0,14	-0,09
K	**0,36**	**0,36**	-0,34	-0,08	-0,27	0,23	**0,43**	-0,09	0,07	-0,01	-0,03	0,07
Ca	-0,32	-0,32	-0,18	-0,07	-0,10	0,02	-0,23	0,17	0,31	0,21	0,07	0,07
Cr	-0,30	-0,31	-0,01	-0,09	-0,17	0,12	-0,09	0,00	-0,01	0,29	-0,25	0,01
Mn	**0,54**	**0,54**	-0,26	0,11	-0,28	0,32	**0,54**	-0,22	-0,08	-0,16	0,05	0,03
Fe	0,06	0,06	-0,08	0,12	0,04	-0,04	-0,03	0,15	0,28	0,16	0,13	-0,02
Ni	**0,68**	**0,68**	-0,21	0,20	-0,29	**0,45**	**0,71**	-0,29	-0,15	-0,35	-0,13	0,08
Cu	**0,67**	**0,67**	-0,29	0,01	-0,20	0,24	**0,60**	-0,05	0,02	-0,28	-0,02	0,17
Zn	0,14	0,14	0,00	0,07	-0,03	0,09	0,15	-0,05	0,01	-0,05	-0,15	-0,07
Pb	-0,04	-0,04	-0,19	-0,17	-0,20	0,06	0,05	-0,03	0,02	-0,02	-0,03	-0,23
Cd	**0,61**	**0,61**	-0,17	0,07	-0,21	0,31	**0,56**	-0,19	-0,21	-0,20	-0,22	-0,03
As	**0,64**	**0,64**	-0,22	-0,03	-0,32	0,30	**0,65**	-0,22	-0,09	-0,22	-0,05	0,16

Vysvětlivky: tučně - statisticky významná korelace ($p < 0,05$)

Org. uhlík v % (C_t) ………. Obsah oxidovatelného uhlíku
Humus v % (C_t 1,724) ……. Obsah humusu
$CaCO_3$ ……………………. Obsah uhličitanů
pH akt. (H_2O) …………….. Aktivní půdní reakce pH/H_2O
pH vým. (KCL) ………….. Výměnná půdní reakce pH/KCl
Titrační acidita mval/100 g . Spotřeba hydroxidu sodného při titraci zeminy
H^{+1} ……………. Výměnný vodík
S mval/100g …... Obsah výměnných bází
T mval/100g …. Maximální sorbční kapacita
V % …………… Stupeň sorbčního nasycení
P_2O_5 …………… Přijatelná kyselina fosforečná
K_2O …………… Přijatelné draslo

ZÁVĚR

Silná korelační závislost byla potvrzena mezi minerálními látkami Mg, Ni, Cu, Cd, As obsaženými v medu a organickým uhlíkem, humusem v půdě a kyselostí. Korelace byla dále potvrzena mezi Mn, K v medu a organickým uhlíkem, humusem v půdě a kyselostí. Závislost mezi Ca v medu a $CaCO_3$ nebyla potvrzena a nebyla potvrzena ani závislost mezi K v medu a K_2O v půdě. Důvodem může být vstup těchto prvků do půdy lidskou činností, která je závislá na pěstovaných plodinách a jejich potřebách k minerálním látkám. Minerální látky, které neřadíme mezi základní nutrienty rostlin, a tedy nejsou využívány v podobě hnojiv, mají proto významnější vliv na určení geografického původu medu než minerální látky běžně používané jako hnojiva.

PODĚKOVÁNÍ

Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projekty: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

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ROZDÍLY FYZIKÁLNĚ CHEMICKÝCH PARAMETRŮ MEDŮ Z VÍCE ÚLŮ JEDNÉ LOKALITY

DIFFERENCES IN PHYSICO-CHEMICAL PARAMETERS OF HONEYS FROM SEVERAL HIVES OF ONE LOCATION

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ABSTRACT

The physicochemical properties and also the colour of the honey vary depending on the location where it was produced. One reason for this may be climatic conditions or the type of honey, but last but not least the composition is also influenced by the different preferences of bee colony in collecting pollen and honeydew. The aim of this work is to compare honey samples in the same locality by means of a test of identity/difference. Specifically, Slovak honeys from the areas of Humenné, Pčoliné, Čukalovce, Bela nad Cirochou and Stakčín were analysed. Differences in physico-chemical parameters as well as in the colour of the honey were found between the samples in the same locality. The highest average compliance value (43 %) was found for the honeys from the Strakčín site. The lowest average agreement (25 %) was found for honeys from the Belá nad Cirochou site.

Key words: beecolony, *Apis melifera*, sustainability, polynation

ÚVOD

Včelí společenství je schopné v krajině zabezpečit plnohodnotné opylení nejen kulturních, ale i původních rostlin. Z pozorování včel se ukazuje, že jednotlivá včelí společenství (úly) mají různou preferenci sbíraného pylu a nektaru, čímž je zabezpečeno opylování více botanických druhů než jenom těch s vysokou atraktivitou (Khan a Ghramh a kol., 2021).

Fyzikálně-chemické parametry medu jsou ovlivněny různými faktory. Obsah vody souvisí zejména se stupněm vyzrálosti medu, zpracováním medu a v ojedinělých případech také s klimatickými podmínkami (Uran a kol. 2017; Manickavasagam a kol., 2022). Kyselost medu je dána obsahem organických kyselin. Tento parametr se zvyšuje jednak časem, ale také kvašením medu, kdy kvasinky zkvašují cukry za vzniku kyselin. Kyselost ovlivňuje chuť, stabilitu vůči mikroorganismům a také antioxidační aktivitu medu (Cavia a kol., 2007). Vodivost medu je parametr, který obvykle koreluje s podílem medovice v medech. Čím vyšší je vodivost medu, tím je tvořen větším podílem medovice. Existují však i květové medy, které mají vysokou vodivost, jako je například jahodník (*Arbutus unedo*), zvonovec (*Erica*), eukalyptus, lípa (*Tilia* spp.), vřes obecný (*Calluna vulgaris*), meduňka (*leptospermum*) nebo čajovník (*Melaleuca spp.)* (Pita-Calvo & Vázquez, 2017). Z chemických parametrů charakterizují danou lokalitu také sacharidy, protože nektar rostlin má různý obsah glukózy a fruktózy. Lze ale pozorovat také obsah dalších sacharidů, jako jsou například trehalóza, maltóza, rafinóza apod. (Pascual-Maté a kol., 2018). Národní legislativa a evropské předpisy (Vyhláška 76/2003 Sb., Směrnice Rady 2001/110/ES) tento fakt reflektují, a proto jsou pro některé druhové medy stanoveny výjimky, například pro sacharózu u citrusových medů nebo levandulového medu.

Barva medu jako fyzikální parametr nereprezentuje konkrétní látku. Na barvu má vliv obsah fenolických látek, které jsou rozpuštěné v medu. Dále je barva ovlivněna množstvím a barvou pylu a v neposlední řadě také obsahem minerálních látek, množstvím krystalů sacharidů, a obsahem vody. Pro měření barvy se běžně používá stupnice Pfund, i když v poslední době se ukazuje jako lepší měření v barevném spektru CIE Lab (Bodor a kol., 2021; Smetanska a kol., 2021).

Cílem práce bylo zjistit, jestli rozdílné včelí společenství bude mít vliv na fyzikálně-chemické složení medů, které pocházejí z jedné lokality.

MATERIÁL A METODIKA

Analyzováno bylo 20 medů ze Slovenské republiky. Fyzikálně-chemické parametry byly měřeny podle metodického postupu Bogdanov (2009). Konkrétně se analyzoval obsah vody, vodivost, a obsah fruktózy, glukózy, sacharózy, turanózy, maltózy, trehalózy, melibiózy a melezitózy. CIE Lab bylo měřeno podle Bodor a kol. (2021). Medy byly z lokalit Humenné, Pčoliné, Čukalovce, Belá nad Cirochou, Stakčín. Z každé lokality byly analyzovány 4 vzorky medů, které byly vzájemně srovnány testem shodnosti/rozdílnosti s procentuálním vyjádřením shody, statistickým softwarem Xlstat 2024 (Lumivero, USA).

VÝSLEDKY A DISKUZE

Rozdílnost medů z různých úlů na jednom stanovišti je mezi včelaři diskutované téma. Nejsou však zatím známé přesné důvody, proč k tomu dochází. Rovněž popis rozdílnosti medu je nejčastěji založen na senzorickém popisu. V této práci jsou fyzikálně-chemické parametry porovnány sumárně testem shodnosti. Pro lokalitu Humenné (H) je vzájemná shodnost uvedena v tabulce 1.

Tabulka č. 1, Shodnost fyzikálně chemických parametrů medu z lokality Humenné.

Společenství	H1	H2	H3	H4
H1	*	0,429	0,357	0,214
H2	0,429	*	0,429	0,357
H3	0,357	0,429	*	0,214
H4	0,214	0,357	0,214	*

* - 1,00 (100 %), H1-H4 včelí stanoviště 1 až 4.

Výsledky ukazují, že ani v jednom případě nebyly medy z jedné lokality totožné, nejblíže byla společenství H1 a H2, kde byla podobnost 43 % a stejná shoda byla u společenství H3 a H2. Vzorek H4 se od ostatních lišil nejvíce a průměrná shoda byla jenom 26 %. Průměrná shoda pro lokalitu Humenné byla 33 %. Tento med byl charakterizován včelařem jako med květový s příměsí akátu. Právě snůška akátu může být důvodem rozdílů mezi jednotlivými společenstvy. Akát je pro včely atraktivní, avšak kvete kratší dobu v závislosti na teplotě (Alilla a kol., 2022). Včelí společenství z této lokality, které bylo v době kvetení akátu v nejvyšším stupni rozvoje (největší zastoupení létavek), bylo schopno zachytit tuto snůšku nejvíce. Slabě rozvinuté společenství je schopné zabezpečit zdroje nektaru, ale s ohledem na menší počet létavek, rozloží snůšku na delší období, a má tedy menší podíl krátkodobě významných zdrojů, v tomto případě akátu.

Další oblastí, ze které byly analyzovány medy, je Pčoliné (P). Medy z této lokality byly označené, jako vícedruhové květové medy tmavé. Hodnoty shodnosti jsou uvedeny v tabulce 2.

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Annex 5: Rozdíly fyzikálně chemických parametrů medů z vice úlů jedné lokality
(Differences in physico-chemical parameters of honeys from several hives of one location)

Tabulka č. 2, Shodnost fyzikálně chemických parametrů medu z lokality Pčoliné.

Společenství	P1	P2	P3	P4
P1	*	0,429	0,429	0,429
P2	0,429	*	0,357	0,429
P3	0,429	0,357	*	0,429
P4	0,429	0,429	0,429	*

* - 1,00 (100 %), P1-P4 včelí stanoviště 1 až 4.

Z výsledků medů z lokality Pčoliné vyplývá, že největší rozdíly byly zaznamenány mezi medy P2 a P3 (36 %). Ostatní vzorky měly totožnou shodu 43 %. Průměrná hodnota shody pro vzorky medu z lokality Pčoliné je 42 %.

Třetí lokalitou, ze které byly medy získány, byly Čukalovce (Č). Medy z této lokality byly označeny, jako vícedruhové květové medy tmavé. Shodnost mezi jednotlivými vzorky je uvedena v tabulce 3.

Tabulka č. 3, Shodnost fyzikálně chemických parametrů medu z lokality Čukalovce.

Společenství	Č1	Č2	Č3	Č4
Č1	*	0,429	0,357	0,429
Č2	0,429	*	0,286	0,286
Č3	0,357	0,286	*	0,357
Č4	0,429	0,286	0,357	*

* - 1,00 (100 %), Č1-Č4 včelí stanoviště 1 až 4.

U medů z lokality Čukalovce je největší shoda mezi Č1 a Č2 (43 %) a také mezi Č1 a Č4 (43 %). Největší rozdíl byl zjištěn mezi Č2 a Č3 (27 %) a také mezi Č2 a Č4 (27 %). Průměrná hodnota shodnosti pro medy z lokality Čukalovce je 36 %

Hodnoty shodnosti medů z lokality Belá nad Cirochou (B) jsou označeny v tabulce 4. Tyto medy byly označeny jako květové medy tmavé.

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Annex 5: Rozdíly fyzikálně chemických parametrů medů z vice úlů jedné lokality
(Differences in physico-chemical parameters of honeys from several hives of one location)

Tabulka č. 4, Shodnost fyzikálně chemických parametrů medu z lokality Belá nad Cirochou.

Společenství	B1	B2	B3	B4
B1	*	0,286	0,214	0,214
B2	0,286	*	0,286	0,214
B3	0,214	0,286	*	0,286
B4	0,214	0,214	0,286	*

* - 1,00 (100 %), B1-B4 včelí stanoviště 1 až 4.

Z výsledků vyplývá, že mezi medy byly velké rozdíly. Největší rozdíl byl zjištěn u vzorku B1 v porovnání se vzorky B3 a B4 (21 %). Největší shoda byla zjištěna u medů B1 a B2 a také mezi vzorky B2 a B3 (29 %). Průměrná shoda medů získaných z lokality Belá nad Cirochou je 25 %. Složení medů od včelstev ze stejné lokality může být ovlivněno mimo jiné také sílou a vitalitou včelstva a také způsobem sběru (Tomczyk a kol., 2019). Dalším důvodem může být výběr květů včelami. Bylo zjištěno, že včely si mohou vybírat květy na základě barvy, typu květenství, či velikost květů. Tyto parametry často souvisí s množstvím nektaru, které rostlina včelám nabízí (Shrestha a kol., 2020; Giurfa a kol., 1995; Duffield a kol., 1993). Pylová preference může být také geneticky podmíněná (Dag a kol., 2005).

Poslední lokalitou, ze které byly porovnány medy byl Stakčín (S). Tyto medy byly označeny jako květové světlé. Výsledky jsou uvedeny v tabulce 5.

Tabulka č. 5, Shodnost fyzikálně chemických parametrů medu z lokality Stakčín.

Společenství	S1	S2	S3	S4
S1	*	0,500	0,429	0,429
S2	0,500	*	0,357	0,429
S3	0,429	0,357	*	0,429
S4	0,429	0,429	0,429	*

* - 1,00 (100 %), S1-S4 včelí stanoviště 1 až 4.

Největší shoda byla mezi medy S1 a S2 (50 %), nejvíce se lišily vzorky medů S2 a S3 (36 %). Průměrná hodnota shody je 43 %, což je nejvyšší hodnota z analyzovaných vzorků medů ze všech lokalit. Malé rozdíly v obsahu vody medů vyprodukovaných ve stejné lokalitě potvrzuje také Bijlsma a kol. (2006). Autoři také potvrdili rozdíly v obsahu vody u medů produkovaných bezžihadlovými včelami (mají vyšší obsah vody) ve srovnání s medy od *Apis mellifera* v rámci stejné lokality.

ZÁVĚR

Výsledky této práce potvrdily, že jednotlivá včelí společenství produkují med o různém fyzikálně chemickém složení, což je ve shodě s tvrzením včelařů. Nejvyšší průměrná shoda byla 43 % u květového světlého medu z lokality Stakčín. Nejnižší průměrná shoda 25 % byla u květového tmavého medu z lokality Belá nad Cirochou. Rozdíly ve shodnosti výsledků by mohly být způsobeny nejen různou preferencí včelího společenství, ale také různým stupněm rozvoje včelstev v průběhu medové snůšky, která je multifaktoriálně ovlivněna řadou faktorů od nemocí až po včelařskou praxi.

PODĚKOVÁNÍ

Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projekty: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

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APPLICATION COLOUR MEASUREMENTS IN HONEY AUTHENTICATION – A CASE STUDY

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Honey authentication is gaining growing importance in the emerging conditions of current adulteration trends. As a highly priced products, the value market of honey strongly depends on its origin. To certify this latter, ususally the combination of three methods, i.e. physicochemical, melissopalynology and sensory analysis are performed. which include colour analysis too. In general honey colour analysis is performed by the Pfund colour measurement. This comprises more evaluation classes, based on the numerical Pfund values.However, even within one group there can be great differences between the exact colour parameters. Moreover, this technique is quite subjective. Due to these backdraws, there is a need for a more precise and accurate method, that possesses a better repeatability as well. Therefore, a self-developed spectroscopic method was developed, which is easy to use and calculates automatically all the colour parameters, such as CIEL*a*b* and Pfund. It can also reveal more subtle differences in samples colours.[1] For the measurements 4 different honeys from 5 locations in Hungary, Poland and Slovakia were collected directly from beekeepers. The CIEL*a*b* and Pfund values were determined from the full transmittance spectra of the 50 % w/V sample solutions in the visible range (380-780 nm). The results were evaluated by multivariate analysis using PCA. Based on the plots obtained, we can assume that the samples show a distinct discrimination pattern. It is also visible that the Hungarian and Polish Acacia samples do not overlap, this suggesting a strong effect of the geographical origin.

Acknowledgment: The project was supported by the government of the Czech Republic, Hungary, Poland and Slovakia by the grant agency Visegrad Grants from the International Visegrad Fund. Project name: Sustainable Beekeeping in the Visegrad Group, number: 22220064. Special thanks are dve to the Hungarian Beekepers Association (Országos Magyar Méhészeti Egyesület) for providing the Hungarian honey samples.

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Annex 7: Určenie krajiny pôvodu na základě minerálneho profile medu
(Determination of the landscape of the basin on the basis of the mineral profile of honey)

URČENIE KRAJINY PÔVODU NA ZÁKLADE MINERÁLNEHO PROFILU MEDU

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Vlastnosti medu sú ovplyvnené prostredím, z ktorého pochádza. Niektoré faktory prostredia sú pre jednotlivé stanovištia premenlivé, niektoré sú pre zmenu ovplyvnené klimatickými podmienkami. Jedným zo základných analýz medu, ktoré nesú najviac informácií o geografickom pôvode medu je minerálny profil medu. Minerálny profil medu je ovplyvnený aj druhom znášky, kedy výrazne väčšie zastúpenie minerálnych látok je pri medoch medovicových, a nižšie pri medoch kvetových[1]. Ani nebolo prekvapením, že najmenej zastúpené sú minerálne látky pri medoch kŕmených cukrom a cukrovými sirupmi. Dôvodom vzťahu minerálneho profilu medu s lokalitou je, že množstvo a zastúpenie minerálnych látok je silne ovplyvnené minerálnym profilom pôdy a podložia. V rámci tejto štúdie bolo vyhodnotených 20 medov z Česka, Maďarska, Poľska a Slovenska. Medzi porovnávanými krajinami bol potvrdený rozdiel v minerálnom profile, schopnosť presne určiť pôvod medu bola podľa diskriminačnej analýzy 86,5 %. Medy na základe minerálneho zloženia, vytvorili samostatné skupiny pre slovenské a české medy. Pri medoch z Poľska a Maďarska bol zaznamenaný prekryv, ktorý je tiež dôvodom nižšej presnosti učenia krajiny pôvodu. Odlíšiť na základe minerálneho profilu bolo možné aj lipové a gaštanové medy pôvodom z Maďarska. Toto zistenie je v súlade so zahraničnými autormi[2, 3]. Minerálny profil medu teda umožňuje nielen určiť geografický pôvod medu ale aj určiť botanický pôvod. Svoje uplatnenie minerálny profil nachádza aj na určenie ekologicky zaťažených oblastí. Med z týchto oblastí často obsahuje stopové množstvo kontaminujúcich polutantov, čo na druhej strane umožňuje identifikáciu týchto oblastí aj z medu a analýza medu na minerálny profil môže fungovať ako monitoring prostredia z ktorého pochádza, ale treba brať do úvahy aj vyššie zastúpenie kontaminujúcich polutantov aj v medovicových medoch[4].

Poďakovanie: Projekt bol podporený vládou Českej republiky, Maďarska, Poľska a Slovenska grantovou agentúrou Visegrad Grants z International Visegrad Fund. Názov projektu: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

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Annex 8: Kvalita a autenticita medu v zemích Visegrádské čtyřky
(Quality and authenticity of honey in the Visegrad Four countries)

KVALITA A AUTENTICITA MEDU V ZEMÍCH VISEGRÁDSKÉ ČTYŘKY

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Kvalitní a autentický med je jedním ze základních předpokladů udržitelného včelaření. Včelaření je sice pro hobby včelaře koníček a ekonomický příjem není na prvním místě, pro komerční včelaření je ale nutné, aby výkupní cena medů odpovídala skutečným nákladům. Faktem také je, že podle německé studie[1] je nejvyšší ziskovost u medů s konkrétně deklarovanou zemí původu a překvapivě bioprodukce výrazně nezlepšuje rentabilitu včelaření. Pro včelaře je proto závažným problémem dovoz levných medů ze zahraničí. Součástí tohoto problému je také nízká kvalita dovezených medů, kdy podle zjištění EU bylo až 66 % medů z Číny falšováno přídavky cizích cukrů, a medy z Ukrajiny byly falšovány cizími cukry z 13 %. Obě tyto země jsou přitom majoritními dovozci do EU[2]. Důležitým aspektem je schopnost určit autentické medy v rámci kontrolní činnosti. Pro tuto analýzu existuje více metod přístupu. Nejčastěji se setkáváme s moderními metodami jako je izotopová analýza[3], nebo s přístupem založeným na stanovení více parametrů. V rámci této studie bylo analyzováno 20 medů z Česka, Maďarska, Polska a Slovenska. Hodnoceny byly fyzikálně-chemické parametry medu a použitou statistickou metodou byla lineární diskriminační analýza. Výsledky potvrdily možnost určení země původu z analyzovaných parametrů s pravděpodobností 89 %. Vhodnost těchto metod pro diskriminaci potvrdili také v polské studii[4]. I když tento výsledek poukazuje na možnost průkazu původu medu na základě fyzikálně-chemických metod, pro dozorovou činnost je zapotřebí dosáhnout vyšší přesnost metody, ideálně nad 95 %. Pro úspěšnou aplikaci více-faktorové analýzy pro určení země původu medu je proto zapotřebí použít některé z dalších měřitelných veličin u medu a zvýšit tak přesnost tohoto průkazu. S ohledem na blízkost těchto zemí může být s určením problém, nicméně charakteristika národních medů umožní odlišit tyto medy od medů, které jsou ze vzdálenějších oblastí, ve kterých jiné klimatické podmínky, včelí pastva či chovatelské postupy vedou k odlišným fyzikálně-chemickým vlastnostem medu.

Poděkování: Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projektu: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

Visegrad Fund

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Exploring the Influence of Soil Types on the Mineral Profile of Honey: Implications for Geographical Origin Prediction

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Citation: Schmidlová, S.; Javůrková, Z.; Tremlová, B.; Hernik, J.; Prus, B.; Marcinčák, S.; Marcinčáková, D.; Štarha, P.; Čížková, H.; Kružík, V.; et al. Exploring the Influence of Soil Types on the Mineral Profile of Honey: Implications for Geographical Origin Prediction. *Foods* **2024**, *13*, 2006. https://doi.org/10.3390/foods13132006

Academic Editors: Hongyan Liu, Hongtao Lei, Boli Guo and Ren-You Gan

Received: 14 May 2024
Revised: 20 June 2024
Accepted: 21 June 2024
Published: 25 June 2024

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Abstract: Honey contains a wide range of inorganic substances. Their content can be influenced, i.e., by the type of soil on which the bee pasture is located. As part of this study, the mineral profile of 32 samples of honey from hobby beekeepers from the Czech Republic wasevaluated and then compared with soil types in the vicinity of the beehive location. Pearson's correlation coefficient was used to express the relationship between mineral substances and soil type. There was a high correlation between antroposol and Zn (R = 0.98), Pb (R = 0.96), then between ranker and Mn (0.95), then regosol and Al (R = 0.97) ($p < 0.05$). A high negative correlation was found between regosol and Mg (R = −0.97), Cr (R = −0.98) and between redzinas and Al (R = −0.97) ($p < 0.05$). Both positive and negative high correlations were confirmed for phaeozem. The CART method subsequently proved that the characteristic elements for individual soil types are B, Ca, Mg, Ni, and Mn. The soil types of cambisol, fluvisol, gleysol, anthrosol, and kastanozem had the closest relationship with the elements mentioned, and it can therefore be assumed that their occurrence indicates the presence of these soil types within the range of beehive location.

Keywords: traces elements; Czech beekeepers; sustainability; GIS

1. Introduction

Honey is very variable in its composition. In addition to basic substances such as sugars and water, honey also contains a diverse array of mineral components, including essential minerals and potentially toxic elements. The composition of honey is strongly influenced by natural and anthropogenic influences. Although mineral substances and potentially toxic elements subgroups are less significant components of honey by volume, they play a vital role in evaluating its quality [1,2].

It is essential that honey is free of potential contaminating substances. It is estimated that the honey bee forages on plants growing in an area from 7 to 28 km^2, depending on their need for food and its availability [3]. Honey bees collect pollen as a source of amino acids, fats, minerals, proteins, starch, sterols and vitamins. A diverse selection of floral sources is required for a bee to get all her nutritional needs [4]. Honey bees interact with a variety of matrices that can be measured for contaminant accumulation, such as freshly collected pollen, honey, stored pollen, and beeswax. Honey composition is the result of many processes, is useful for gathering information about the environment, and can be a suitable bioindicator of environmental pollution [5,6].

The idea of using bees and honey in the field of the environment goes back to J. Svoboda (1961) and E. Crane (1984), who believed that bees could provide valuable data on the environmental impact the authors proved that potentially toxic elements such as Cd, Pb and metalloid As in bees and bee products correspond as indicators of environmental pollution [7,8]. In research from 1962, J. Svoboda's team recorded an increase in the content of the radionuclide strontium 90 in the environment through the monitoring of bees—most likely as a result of nuclear testing. In the following years, bees were increasingly used to monitor environmental pollution by potentially toxic elements in geological and urban surveys [9,10]. As Leita et al. (1996) [11] suggested, a network of hives located next to polluted areas can provide data for monitoring heavy metal emissions from specific sources. Ruschioni et al. (2013) [12] also show that trends in metal contamination correlate with weather patterns and anthropogenic activities in the region where samples were obtained. Honey has nutritional, medicinal, and prophylactic properties, which are contributed to by its chemical components. The concentration of mineral compounds ranges from 0.1% to 1.0%. In comparison with nectar honeys, honeydew honeys are higher in minerals, resulting in higher electrolytic conductivity [13]. Also, the mineral content influences the color and taste of honeys. The higher the quantity of metals and the darker the color is, the stronger the taste they will have [14]. The mineral profile is dominated by potassium, followed by calcium, magnesium, sodium, sulfur, and phosphorus. Trace elements include iron, copper, zinc, and manganese [15,16]. The main mineral substances come mainly from soil and nectar-bearing plants but can also come from anthropogenic sources [17,18].

There are relations between the mineral profile of honey and a soil type [19,20]. According to the international soil classification system, soils are divided into different groups, especially by particle size, texture classes, and mineral composition [21,22].

The Czech Republic has a very diverse spectrum of soil types. The mountains are dominated by coniferous forests, under which podzol soils are formed. In the lowlands, which are a very warm region, chernozems are found. The occurrence of different types of soils is also influenced by altitude, slope, and biota. For example, alluvial soils, for the formation of which sufficient water is essential, are most often found near watercourses [23]. The Czech Geological Survey provides a detailed map of soil types, of which it is possible to evaluate the connection with the location of bee colonies. The mutual relationship between soil type and mineral substances in honey can be used to predict the geographical origin of honey. The aim of this study was to verify the influence of soil types according to the international classification on the mineral profile of honey depending on the total area of the soil type in the beehive location. A partial goal was to verify the correlation dependence of the mineral composition of honey and soil type and to describe the mineral profile depending on the soil type.

2. Materials and Methods

In this study, 32 multifloral honey samples were collected and harvested between 2019 and 2020 in the Czech Republic, Moravia. The honeys were collected from hobby beekeepers and harvested at the University of Veterinary Sciences with the same equipment to eliminate the impact of different harvesters. The pollen profile and locality are summarized in Table S1 and Figure S1. The quantitative melissopalynology analysis was performed with semiautomated acquisition according to the previous study [24].

The World Reference Base for Soil Resources (WRB) classification system [22] was used. The area of WRB for the beehive location was processed by QGIS 3.28 (QGIS Development Team, 2023); soil data were taken from the national geoportal https://geoportal.gov.cz/ (accessed on 1st April 2024) [25], where the soils are classified according to new soil systems [26].

In the collected data, 16 soil types were observed with different area sizes. The area and frequency of each soil type are detailed in Table 1. In general, hive locations were represented by more than one soil type, and the same soil type was observed in different hive locations. The evaluated area of soil type was represented by approximate bee flying distances of 3 km. In total, the 28.27 km^2 for each hive location were evaluated. Honey samples were collected in situ by the research team directly from the hives. The GPS coordinates, land use data, and botanical profiles of the surrounding area were documented in a detailed questionnaire. The GPS coordinates of each hive served as the central point for a 3 km radius buffer zone. Within this defined buffer zone, soil-type data were extracted and analyzed.

Table 1. Soil type frequency and area.

Categories	Frequencies	Lands Area (km^2)	%
Anthrosol	8	24.147	2.669
Cambisol	26	427.149	47.218
Chernozem	7	92.438	10.218
Fluvisol	26	95.405	10.546
Gleysol	21	36.620	4.048
Kastanozem	14	66.888	7.394
Luvisol	13	52.301	5.781
Pararendzina	6	20.171	2.230
Pelozem	6	31.849	3.521
Phaeozem	2	8.905	0.984
Podzol	2	10.307	1.139
Pseudogley	15	20.158	2.228
Ranker	5	1.242	0.137
Regosol	7	11.010	1.217
Rendzinas	4	2.663	0.294
Water Bodies	8	3.388	0.375

The mineral content was determined by Inductively Coupled Plasma Mass Spectrometry ICP-MS 7900 (Agilent, Santa Clara, CA, USA) according to the STN EN 15763 [27], UNI EN 13805 [28], and UNI EN 13804 [29] in honey samples. The B, Na, Mg, Al, K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, As, and Pb content were determined in each sample. The methods, including qualitative parameters, are described in Document S1.

The data were statistically evaluated by Xlstat 2024.2.0 (Adinsoft, Denver, CO, USA). The data follow normal distribution according to the Shapiro–Wilk test. For comparison of mineral content, ANOVA (post-hoc, Tukey HSD) and Pearson correlation coefficient were used. Due to the variation in soil types across different locations, statistical analyses were conducted using weighted correction methods. This approach adjusts for differences in sample size, ensuring that each observation contributes appropriately to the analysis. Weighted corrections were applied to ANOVA, Pearson correlation, and Classification and Regression Trees CART analyses. CART, based on a machine learning algorithm, was used to distinguish soil type based on mineral profile. The location of the hive positions was visualized in Excel 356 (Microsoft, Redmond, WA, USA).

3. Results and Discussion

The average mineral profile of Czech honey and its comparison with other European countries is shown in Table 2. The influence of the habitat of bees on the quality of their honey has been investigated in many studies [17]. Habitats influence the characteristic

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properties of honey, not only from the point of view of sensory uniqueness or the content of biologically active substances but also from the point of view of the mineral profile of the substances contained. The mineral composition of honey has been used in several studies, both for the characterization of bee honey [30–34] as well as a tool for proof of honey adulteration [33,35–38]. The mineral composition of honey is related to bee pasture [39] and is therefore significantly influenced by botanical taxa in the vicinity of the site [40] but also by geographic location and soil composition [41].

The measured values point to differences in the mineral composition of honey, which are related to both its botanical and geographical origin. However, it is clear from the comparison that K (1365.2 mg/kg) is the most represented element, followed by Ca (148.8 mg/kg), Na (36.9 mg/kg), and Mg (35.1 mg/kg). The greatest representation of K agrees with the results of other authors [33,35,39,41]. The representation of Ca and Na may differ depending on the country where the honey comes from when Italy (Latium region) and Turkey (Antolia) had a greater representation of Na [41,42]. In other studies, Ca was more represented, see Table 2, the same finding was confirmed in the Czech Republic (Moravia). All of the major mineral elements did not exceed the tolerable upper intake level (UI) for the adults, which are for Ca, Mg and Zn Fe, 2500, 250, and 25 mg/kg, respectively. For K, Mn, Mn, and Fe, there is not evidence in the EU for tolerable upper intake levels [43–45]. Considering the consumption of 1.7 kg [46] in the EU, honey is not a risk food, even in terms of potentially toxic elements.

Table 2. Comparison of the average mineral profile of honeys from different geographical areas.

	Present Study (Moravia Region) (*n* = 32)	Italy [a] (Siena) (*n* = 50)	Italy [b] (Latium Region) (*n* = 84)	Spain [c] (*n* = 40)	Spain [d] (Galicia) (*n* = 22)	Spain [e] (*n* = **)	Turkey [f] (Anatolia) (*n* = 30)	Ireland [g] (*n* = 50)	Portugal (Castelo Branco) [h] (*n* = 16)	Poland [i] (*n* = 30)	Hungary [j] (*n* = 34)
K (mg/kg)	1365.2	1195	472	1124	1345	1778	296	566	701.87	1585.6	610.2
Ca (mg/kg)	148.8	257	47.7	169	**	113	51	111	28.36	35.52	92.3
Na (mg/kg)	36.9	96.6	96	76	115	279	118	98	31.04	29	**
Mg (mg/kg)	35.1	56.7	37	39	77	136	33	31	74.00	**	17.6
Zn (mg/kg)	3.5	1.82	3.1	3.9	2.0	5.65	2.7	5	1.23	2.6	3.7
Mn (mg/kg)	2.3	1.54	3.0	3.4	5.2	**	1.0	4	2.78	2.72	2.1
Fe (mg/kg)	0.7	3.07	4.5	**	3.7	9.19	6.6	8	0.97	3.8	1.4
B (mg/kg)	11.1	**	**	5.43	**	**	**	**	**	5.17	**

** Not provided, [a] [41]; [b] [34]; [c] [35]; [d] [47]; [e] [29]; [f] [42]; [g] [48]; [h] [49]; [i] [50]; [j] [51].

As already mentioned, there can be more reasons for the different representations of mineral substances. Our study has shown that one of the factors influencing the mineral composition, specifically the content of K, Mg, and Mn, is the type of soil on which the colonies are located. Mineral representation in plants depends on the type of soil and the density of the root system, the amount of precipitation, and the mineral composition of the subsoil [52]. The average values of mineral substances in honey with respect to the soil types of the observed beehive location are indicated in Table 3. The most K was found in honey with a majority of podzol; on the contrary, the lowest amount was found in honeys from phaeozem, chernozem, and pseudogley ($p < 0.05$). Higher K values in some types of soils can be explained by the fertilization of these soils [53]. Podzol soils also yielded higher amounts of Mg in honey ($p < 0.05$). High amounts of Ca were found in the honeys around the gleysols and rankers, but no statistically significant difference was found between the Ca content in the soils.

Table 3. Comparison of the major mineral substance profiles of soil types in honey (mg/kg).

Soil	Al	B	Ca	K	Mg	Mn	Na	Zn
Gleysol	392.2 [a]	9.7 [a]	196.9 [a]	1604.9 [abcd]	34.1 [ab]	1.8 [a]	41.7 [ab]	3.8 [a]
Cambisol	513.1 [a]	10.3 [a]	167.7 [a]	1463.3 [abcd]	34.7 [ab]	2.8 [a]	35.6 [b]	4.1 [a]
Luvisol	431.8 [a]	10.6 [a]	163.9 [a]	1559.6 [abcd]	32.3 [ab]	1.9 [a]	42.8 [ab]	3.7 [a]
Anthrosol	20.6 [a]	14.7 [a]	161.3 [a]	1427.8 [abcd]	35.9± [ab]	1.1 [a]	36.4 [b]	6.3 [a]
Podzol	11 [a]	14.1 [a]	174.7 [a]	2099 [a]	45.7 [a]	2.8 [a]	32.7 [b]	2.9 [a]
Pelozem	25.3 [a]	14.7 [a]	163.9 [a]	1844.6 [abc]	43.7 [ab]	2.5 [a]	32.4 [b]	2.9 [a]
Rendzinas	49.6 [a]	9.6 [a]	152.5 [a]	1884.6 [ab]	33.4 [ab]	4.1 [a]	31.8 [b]	5.3 [a]
Fluvisol	318.1 [a]	10.7 [a]	129.5 [a]	1398.6 [abcd]	33.9 [ab]	2.5 [a]	35.5 [b]	2.9 [a]
Ranker	144.6 [a]	11 [a]	189.2 [a]	1272.6 [abcd]	38.3 [ab]	1.5 [a]	33.2 [b]	2.8 [a]
Kastanozem	553.4 [a]	11.2 [a]	127.6 [a]	963.7 [abcd]	29.2 [ab]	1.7 [a]	35.5 [b]	3.6 [a]
Chernozem	318.2 [a]	11.7 [a]	125.3 [a]	665.1 [cd]	28.6 [ab]	0.5 [a]	45.1 [ab]	3.4 [a]
Pseudogley	54.5 [a]	15.1 [a]	119.2 [a]	666.6 [cd]	29 [ab]	1.4 [a]	32.6 [b]	3.1 [a]
Pararendzina	13.1 [a]	13.7 [a]	115.3 [a]	878.7 [bcd]	32.7 [ab]	1.7 [a]	25.1 [b]	3.6 [a]
Regosol	71.9 [a]	15.7 [a]	133.5 [a]	985.6 [abcd]	30.2 [ab]	1.2 [a]	28.4 [b]	2.7 [a]
Phaeozem	31.9 [a]	9.7 [a]	96.1 [a]	477.7 [d]	26.3 [ab]	0.3 [a]	64 [a]	1.7 [a]
Water Bodies	36.6 [a]	10.7 [a]	109.7 [a]	916.6 [abcd]	24.5 [b]	1.8 [a]	26.5 [b]	2.3 [a]

Different letters mean significant differences between raw ($p < 0.05$).

For B, Al, Ca, Cr, Mn, Fe, Ni, Cu, Zn, As, and Pb, statistical differences in the content of mineral substances in honey and the types of soil were not confirmed. This finding is due to the large variability of the measured values, while differences in the mineral composition of individual soil types were observed (Tables 3 and 4), especially for B, Al, Mn, and Zn ($p > 0.05$).

Table 4. Comparison of the minor mineral substances profiles of soil types in honey (mg/kg).

Soil	As	Cr	Cu	Fe	Ni	Pb
Gleysol	0.008	0.151	0.302	0.787	0.211	0.090
Cambisol	0.006	0.131	0.342	0.717	0.224	0.100
Luvisol	0.007	0.141	0.299	0.796	0.200	0.095
Anthrosol	0.008	0.151	0.370	0.749	0.173	0.086
Podzol	0.009	0.130	0.387	0.576	0.261	0.059
Pelozem	0.009	0.121	0.361	0.562	0.249	0.060
Rendzinas	0.008	0.130	0.366	0.591	0.184	0.072
Fluvisol	0.007	0.111	0.322	0.662	0.165	0.082
Ranker	0.005	0.128	0.425	0.621	0.144	0.066
Kastanozem	0.008	0.109	0.264	0.863	0.148	0.067
Chernozem	0.006	0.113	0.307	0.698	0.126	0.074
Pseudogley	0.005	0.132	0.183	0.562	0.211	0.048
Pararendzina	0.005	0.119	0.223	0.606	0.201	0.070
Regosol	0.006	0.092	0.249	0.502	0.165	0.052
Phaeozem	0.007	0.120	0.256	0.543	0.107	0.055
Water Bodies	0.006	0.100	0.172	0.481	0.127	0.043

Note: As, Cr, Cu, Fe, Ni, and Pb were no significant differences between raw ($p < 0.05$).

The minor mineral substances such as As, Cr, Cu, Fe, Ni, and Pb are summarized in Table 4. Potentially toxic elements such as Pb and metalloid As can contaminate honey due to environmental pollution and Al. Higher concentration in Al in comparison with Pb and As was also confirmed in the Hungarian study, but the total amount of Al was lower than was detected in our study [51]. In our study, statistical differences between soil types and Pb and As were not determined. Cu, Fe, Ni, and Zn are essential nutrients for organisms, including bees and plants. Statistical differences with soil type have not been confirmed (Table 4). Low concentrations of minor mineral substances in honey were also confirmed in other studies [51,54].

In order to better express the relationship between mineral substances and soil types, the Pearson correlation coefficient was further used. The correlation between soil type and mineral substances is shown in Table 5. There was a high correlation between antroposol area and Zn (R = 0.98), Pb (R = 0.96), then between ranker area and Mn (0.95), then regosol area and Al (R = 0.97) ($p < 0.05$). A high negative correlation was between regosol area and Mg (R = −0.97), Cr (R = −0.98) and between the redzinas area and Al (R = −0.97) ($p < 0.05$).

A positive and negative high correlation was also confirmed for phaeozem, but this result is compromised by an error, which is due to the small representation of this soil in the analyzed localities, both in terms of total representation (1%) and frequency (number of occurrences: 2) (Table 5). At the same time, the frequency corresponded to two beehive locations where the phaeozem represented 20% and 10% of the given locality. Further research is still needed to define a conclusion for this type of soil so that it is included in more locations in a wider representation.

The relationship between mineral composition and plants has been confirmed in various studies, mostly focusing on plant mass, leaves, seeds, and roots [55–58]. Several studies [59,60] confirmed the effect of soil type on the nectar production of the nectar-bearing plant called mānuka (*Leptospermum scoparium*). Ca, Mn, and Fe contained in soil types had a positive effect on production. The amount of Ca also affects the number of flowers on plants [61,62]. The influence of soil type on the growth of other honey plants (*Salix caprea* and *Prunus padus*) was confirmed by [61]. On another honey plant, *Allium ursinum*, the influence of soil mineral composition on nectar production was also confirmed, where the influence of phosphorus was confirmed. The influence of humus, K, Fe, and Mn on the number of flowers was confirmed, while Mn also had an influence on the total nectar content. From the above, we expected that the effect on the mineral substances in honey is manifested due to higher nectar-producing capacity and the number of flowers on soils with a suitable mineral composition and a layer of humus. In our study, statistical differences between the type of soil and the content of Ca, Fe, and Mn in honey were not confirmed (Table 3), but the correlation dependence with the type of soil was confirmed (Table 5).

Therefore, methods of higher statistics were applied to verify the relationship between soil type and mineral composition, which allows for the comparison of several variable parameters. Classification and Regression Trees (CART) were utilized. CART is a machine learning algorithm that recursively splits the dataset based on features to predict a target variable (response). It constructs a decision tree suitable for classification, where the target variable represents categories or classes. In regression, the target variable represents a continuous variable. The CART reaches the best correct classification rate in comparison with not supervised (PCA) and supervised (LDA and QDA) classification for mineral substances [36] and for other honey parameters [63].

Table 5. Correlation between the area of soil type and mineral content in honey in the observed localities.

	B	Na	Mg	Al	K	Ca	Cr	Mn	Fe	Ni	Cu	Zn	As	Pb	No. of Locality
Anthrosol	**0.712**	**0.240**	−0.144	0.045	**0.344**	**0.742**	**0.595**	**−0.227**	**0.824**	−0.054	**0.812**	**0.982**	**0.375**	**0.956**	8
Cambisol	−0.013	0.037	−0.034	0.041	**0.087**	**0.243**	**0.191**	0.018	0.031	**0.290**	0.001	**0.263**	**0.087**	−0.027	26
Chernozem	**0.134**	**−0.530**	**−0.176**	**−0.263**	**−0.457**	−0.063	**−0.486**	**−0.370**	**−0.371**	**−0.437**	**−0.291**	**−0.349**	**−0.717**	**−0.357**	7
Fluvisol	**0.329**	**−0.140**	**−0.129**	**−0.139**	**−0.251**	**−0.513**	**−0.387**	**−0.192**	**−0.181**	**−0.337**	**−0.287**	**−0.356**	0.026	**−0.139**	26
Gleysol	**−0.674**	**0.519**	**−0.343**	−0.163	**0.344**	**0.296**	**0.574**	**−0.457**	**0.237**	**−0.372**	**−0.383**	−0.166	**0.489**	−0.172	21
Kastanozem	**−0.510**	0.001	**−0.594**	**−0.169**	**−0.339**	**−0.479**	**−0.215**	−0.077	**−0.199**	**−0.452**	**−0.444**	**−0.301**	**0.140**	**−0.375**	14
Luvisol	**−0.187**	0.103	−0.037	**−0.319**	**0.405**	**0.753**	**0.573**	**−0.489**	−0.148	−0.035	**−0.328**	**0.159**	**0.267**	**−0.266**	13
Pararendzina	**0.585**	**−0.333**	0.180	**−0.636**	**−0.822**	**−0.635**	0.007	**−0.517**	**0.293**	0.196	**−0.569**	**−0.294**	**−0.669**	−0.081	6
Pelozem	**−0.210**	−0.158	−0.057	**−0.306**	**0.218**	**0.285**	**0.259**	0.138	0.027	−0.062	0.050	**−0.239**	0.026	**−0.285**	6
Phaeozem	**−0.978**	**0.978**	**−0.978**	**−0.978**	**0.978**	**−0.978**	**−0.978**	**−0.978**	**−0.978**	**−0.978**	**0.978**	**−0.978**	**0.978**	**0.978**	2
Podzol	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
Pseudogley	**0.458**	**−0.440**	**−0.503**	**−0.448**	**−0.530**	**−0.374**	−0.238	**−0.534**	0.047	**−0.539**	**−0.583**	**−0.520**	−0.178	**−0.761**	15
Ranker	−0.247	0.235	0.687	−0.559	0.709	0.818	0.713	**0.954**	0.288	0.169	0.598	−0.386	0.450	−0.235	5
Regosol	**0.629**	**−0.741**	**−0.971**	**0.973**	**−0.946**	**−0.943**	**−0.982**	**−0.723**	**−0.886**	**−0.930**	**−0.906**	**−0.638**	**−0.568**	**−0.588**	7
Rendzinas	0.165	0.290	**0.796**	**−0.970**	**0.809**	0.485	**0.704**	0.139	0.304	0.471	0.629	0.375	**0.929**	0.387	4
Water Bodies	−0.107	−0.233	**−0.932**	−0.046	−0.366	−0.431	−0.085	−0.484	−0.182	**−0.698**	**−0.684**	−0.242	0.512	−0.560	8

Value in bold means significant correlation ($p < 0.05$); dark grey means positive correlation higher than 95%; light grey higher than 90%; dark blue negative means correlation higher than 95%; and light blue higher than 90%.

According to the CART, the B, Ca, Mg, Ni, and Mn in honey samples are characteristic of all soil types in our study. The soil types of cambisol, fluvisol, gleysol, anthrosol, and kastanozem were most closely related to the above-mentioned mineral substances found in honey and can, therefore, be assumed to have a major influence on the mineral content of honey (Table 6). An overall summary of the classification is provided in Figure S2. Cambisol and fuvisol are the most common soils in the Czech Republic. While cambisols are represented both in hilly areas and uplands and in mountains; fuvisols, on the other hand, were formed mainly in lowlands, especially along larger rivers [64]. In the Czech Republic, 58% of agricultural land is of the cambisol type [65]. These soils are poor in minerals; thus, in order to achieve adequate production, crops grown on them must be regularly fertilized, which affects their mineral profile [66]. According to CART, therefore, honeys with a large proportion of cambisol were mainly represented by a low content of B, Ca, and Mg, with the exception of the Ni content in honey, which increased with a larger area of cambisol in the vicinity of bee colonies.

Table 6. Regression classification rules for mineral substances.

Nodes	Soil (Prediction)	Rules
Node 1	Cambisol	All cases
Node 2	Cambisol	If B ≤ 14.59 then Soil = Cambisol in 62.9% of cases
Node 3	Cambisol	If B (14.59; 15.87] then Soil = Cambisol in 8.8% of cases
Node 4	Cambisol	If B (15.87; 16.49] then Soil = Cambisol in 10% of cases
Node 5	Gleysol	If B (16.49; 17.05] then Soil = Gleysol in 11.8% of cases
Node 6	Fluvisol	If B > 17.05 then Soil = Fluvisol in 6.5% of cases
Node 7	Fluvisol	If B ≤ 14.59 and Ca ≤ 162.10 then Soil = Fluvisol in 41.8% of cases
Node 8	Cambisol	If B ≤ 14.59 and Ca (162.10; 179.20] then Soil = Cambisol in 5.3% of cases
Node 9	Cambisol	If B ≤ 14.59 and Ca (179.20; 189.20] then Soil = Cambisol in 5.3% of cases
Node 10	Anthrosol	If B ≤ 14.59 and Ca (189.20; 215.30] then Soil = Anthrosol in 2.4% of cases
Node 11	Cambisol	If B ≤ 14.59 and Ca > 215.30 then Soil = Cambisol in 8.2% of cases
Node 12	Cambisol	If B (14.59; 15.87] and Mg ≤ 30.22 then Soil = Cambisol in 4.1% of cases
Node 13	Anthrosol	If B (14.59; 15.87] and Mg > 30.22 then Soil = Anthrosol in 4.7% of cases
Node 14	Cambisol	If B (15.87; 16.49] and Ca ≤ 109.60 then Soil = Cambisol in 8.2% of cases
Node 15	Cambisol	If B (15.87; 16.49] and Ca > 109.60 then Soil = Cambisol in 1.8% of cases
Node 16	Kastanozem	If B (16.49; 17.05] and Ni ≤ 0.13 then Soil = Kastanozem in 5.9% of cases
Node 17	Cambisol	If B (16.49; 17.05] and Ni (0.13; 0.27] then Soil = Cambisol in 4.1% of cases
Node 18	Cambisol	If B (16.49; 17.05] and Ni > 0.27 then Soil = Cambisol in 1.8% of cases
Node 19	Anthrosol	If B > 17.05 and Mg ≤ 34.69 then Soil = Anthrosol in 4.7% of cases
Node 20	Fluvisol	If B > 17.05 and Mg > 34.69 then Soil = Fluvisol in 1.8% of cases
Node 21	Fluvisol	If B ≤ 14.59 and Ca ≤ 162.10 and Mg ≤ 31.49 then Soil = Fluvisol in 29.4% of cases
Node 22	Cambisol	If B ≤ 14.59 and Ca ≤ 162.10 and Mg (31.49; 37.11] then Soil = Cambisol in 4.1% of cases
Node 23	Cambisol	If B ≤ 14.59 and Ca ≤ 162.10 and Mg (37.11; 42.41] then Soil = Cambisol in 4.1% of cases
Node 24	Anthrosol	If B ≤ 14.59 and Ca ≤ 162.10 and Mg > 42.41 then Soil = Anthrosol in 4.1% of cases
Node 25	Cambisol	If B ≤ 14.59 and Ca (179.20; 189.20] and Mg ≤ 37.65 then Soil = Cambisol in 2.9% of cases
Node 26	Cambisol	If B ≤ 14.59 and Ca (179.20; 189.20] and Mg > 37.65 then Soil = Cambisol in 2.4% of cases
Node 27	Cambisol	If B ≤ 14.59 and Ca > 215.30 and Mn ≤ 2 then Soil = Cambisol in 7.1% of cases
Node 28	Cambisol	If B ≤ 14.59 and Ca > 215.30 and Mn > 2 then Soil = Cambisol in 1.2% of cases

The presence of fluvisol in the vicinity of the beehive location was manifested by a low content of B, Ca, and Mg in honey (29.4% of cases) or a low content of B and Ca (41.8% of cases) but in some cases, the presence of this type of soil led to a high content of B (6.5% of cases). These differences are explained by the type of soil, where fluvisol represents river sediments that can be affected by anthropogenic activity [67]. This fact is also indicated by the high content of Pb (Table 3), although in the discrimination according to CART, Pb was not significant, which is caused by the variability of this factor. Another type of soil that has been confirmed to have an effect on the mineral composition of honey is anthrosol. This type of soil is significantly transformed by human activity, mostly with originally less fertile soil [68], which, within the CART discrimination, was manifested by a

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higher representation of Ca and Mg. A high content of Ca and Mg is typical for anthrosol, while their higher content is due to both anthropogenic activity and sandy or sandstone subsoil [68,69]. Another type of soil influencing the mineral profile of honey, according to CART, was kastanozem. This type of soil is typical for pastures, steppes, meadows, and anthropogenic analogs [70]. Kastanozem was manifested by a high content of B and a low content of Ni. These soils are characterized by available Ca, Mg, and Na cations. In our study, only a higher Na content (Table 3) was confirmed in honey in relation to the amount of kastanozem in the location of the bee colonies. The content of B and Ni can be affected by anthropogenic activity (fertilization), but there is not enough information in the scientific literature about its content and availability for plants. Pollution as the reason for their higher content cannot be assumed because other metals such as Pb, As, Cu, and Zn have not been confirmed in honey.

4. Conclusions

The mineral profile of honey can be influenced, among mechanisms, by the type of soil on which the beehive is located and which occurs within its flying range. In this study, positive high correlations were confirmed with certain soil types and specific elements, namely phaeozem with Na and K, as well as ranker with Mn, regosol with Al, and anthrosol with Zn and Pb, while a negative correlation between phaeozem with B, Mg, Al, Ca, Cr, Mn, Fe, Ni, Zn, regosol with Mg, Cr, and rendzinas with Al ($p < 0.05$). The higher statistics methods subsequently proved that some elements are characteristic of the given soil type. Using CART analysis, the linear regression dependence between Ca, B, Mg, and Mn and the cambisol, anthrosol, fluvisol, and kastanozem soils was confirmed. The mutual relationship between soil type and mineral substances in honey can be used to predict the geographical origin of honey. When working with national map data, soil profiles can be used to predict the mineral profile of honey using minerals such as B, Ca, Mg, Ni, and Mn and subsequently authenticate its geographical origin.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/foods13132006/s1, Table S1: Pollen profile of analyzed samples; Figure S1: Location of analyzed samples, Figure S2: CART Classification tree of soil types; Document S1: ICP-MS 7900 methods.

Author Contributions: Conceptualization, M.P. and B.P.; methodology, D.T., J.H. and Z.B.; validation, H.Č., P.Š., D.M., J.B. and V.K.; formal analysis, S.S., V.K. and S.M.; resources, C.B., Z.J., S.M., J.H. and D.T.; data curation, M.P.; writing—original draft preparation, S.S. and M.P.; writing—review and editing, D.T., H.Č. and D.M.; visualization, Z.J.; supervision, B.T.; project administration, M.P.; funding acquisition, M.P. All authors have read and agreed to the published version of the manuscript.

Funding: The project is financed by the governments of the Czech Republic, Hungary, Poland, and Slovakia through Visegrad Grants from the International Visegrad Fund No. 22220064. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article and Supplementary Materials; further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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PREDIKCE ZDROJŮ SNŮŠKY VČEL POMOCÍ GEOGRAFICKÝCH INFORMAČNÍCH SYSTÉMŮ

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Důležitým aspektem pro včelaření je zabezpečit vhodnou a nutričně bohatou snůšku pro včely. Lze toho dosáhnout kočováním v krajině, vhodně zvoleným osevným postupem, výsadbou keřů a stromů v krajině, nebo také vhodně zvoleným stanovištěm. I když ne vždy máme na výběr, kde včelí stanoviště umístit, zjistit vhodnost stanoviště má své nesporné výhody. Pro vytvoření modelu určujícího vhodnost stanoviště byla v práci použita data z volně přístupné evropské databáze CORINE Land Cover[1], která zahrnují základní rozdělení a charakterizaci krajiny (půdní pokryv). Analyzováno bylo 32 medů z České republiky. Vztah k půdnímu pokryvu měly z potvrzených taxonů zejména druhy: Helianthus sp., Robinia sp, Campanula sp, Brasica sp, Aesculus sp., Rhamnus sp. Lotus sp. Thymus sp., Lythrum sp., Phacelia sp., Phagopyrum sp., Aruncus sp. Jejich vztah byl potvrzen k půdnímu pokryvu typů pastviny a orná půda nezavlažovaná. Dále slabší vztah těchto taxonů byl potvrzen v případě měst, komerčních ploch, převážně zemědělských území s příměsí přirozené vegetace a smíšených lesů. S ohledem na uvedené taxony lze předpokládat rovnoměrnou snůšku jak nektaru, tak pylu a tedy i dostatečnou výživu pro včelstvo a pro produkci medu. Zjištěné výsledky umožnují zjistit na základě analýzy lokality plánovaného včelstva z evropské databáze CORINE Land Cover zastoupení tohoto typu půdního pokryvu v doletové vzdálenosti včel a tedy predikovat vhodnost plánované lokality. S ohledem na výsledky této studie by minimální plocha půdního pokryvu v doletové vzdálenosti včel měla být pro pastviny 5,5 % a pro ornou půdu nezavlažovanou 15,5 %. Toto zastoupení vedlo k dostatečné snůšce pozdního jara, kdy zdrojem byla zejména řepka setá. V pozdějších obdobích se na snůšce podílely štírovník, slunečnice, rostliny rodu mateřídouška. Model byl připraven pro doletovou vzdálenost 3 km od stanoviště. Určitou variabilitu lze očekávat i v tomto parametru, doletová vzdálenost podle nejnovějších studií je 2,2 km pro 90 % včel[2]. Proměnlivým faktorem je také osevní postup, kdy lze očekávat v případě zemědělské půdy přítomnost řepky seté, která patří mezi významný zdroj snůšky včel v České republice[3].

Poděkování: Projekt byl podpořen vládou České republiky, Maďarska, Polska a Slovenska grantovou agenturou Visegrad Grants z International Visegrad Fund. Název projekty: Sustainable Beekeeping in the Visegrad Group, číslo: 22220064.

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Title: Sustainable beekeeping in Visegrad group - Final Report

Editor: associate professor DVM. Matej Pospiech, Ph.D.

Contributors: Matej Pospiech, Zdeňka Javůrková, Marie Bartlová, Simona Ondruchová, Helena Čížková, Vojtěch Kružík, Dalibor Titěra, Józef Hernik, Barbara Prus, Slavomír Marcinčák, Dana Marcinčáková, Csilla Benedek, Zsanett Bodor

Published by: University of Veterinary Sciences Brno

Supported by: International Visegrad Fund

Number of pages: 88

Issue: first

Publication year: 2024

Publication place: Brno

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ISBN 978-80-7305-959-0