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Climate Zones and Morphometric Parameters of *Apis mellifera carnica* Bees

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Abstract: The *Apis mellifera carnica* is the most prevalent bee population distributed in the different climate zones of Kazakhstan. In this study, ten bee colonies of the *A.m. carnica* breed from six bee farms were selected for research, from six climate zones: Desert, semi-desert, steppe, forest-steppe, foothill, and mountain, and different regions: Southern, northern, eastern, western Kazakhstan. During the period of full activity, 30 samples of the right front wings, legs, proboscis, hooks, sternite, and tergite were taken from each bee family. The obtained experimental material was processed by methods of variational statistics (variational series, arithmetic mean, arithmetic mean error, Coefficient of Variation (CV), and correlation coefficient). The results revealed that the highest value of the cubital index was found in bee samples living in a semi-desert, while no significant differences were recorded between the dumbbell index indicators of the bee samples from different zones. The discoidal displacement value was the highest in bees of the semi-desert. A significant ($P<0.05$) difference was established between the indicators of this trait in bees in forest-steppe, foothill, and mountain zones. According to the development of exterior features, the bee populations were divided into 4 zones. Thus, the highest proboscis length and sternite length and width were found in bees of the foothill. The highest tergite width and length, wax mirror length and width, and the number of hooks were in the bees of the steppe zone. The tarsal index was developed in bees living in the mountain zone and the length and width of the right wing were developed in bees living in the forest-steppe zone. The acquired abilities can be inherited in the future, which will allow the creation of new ecotypes through breeding work.

Keywords: Climate Zones, Cubital Index, Discoidal Displacement, Dumbbell Index, Morphometry

Introduction

In Kazakhstan, three breeds of bees are bred and used: *Apis mellifera carnica* (*A.m. carnica*), *Apis mellifera Carpathian* (*A.m. carpathian*), *Apis mellifera mellifera* (*A.m. mellifera*), as well as the local population of bees (Bissembayev *et al*., 2023). According to statistics, there are 200 beekeeping farms in Kazakhstan, more than 196.0 thousand breeding families and according to the republican chamber of Beekeepers, there are about 45.0 thousand breeding bee families. According to the number of bee colonies, the *A.m. carnica* breed is dominating with 61.6% of the total number of bees in the republic, *A.m. Carpathian* with 29.4% and the remaining 9 % is accounted for imported breeds and local bee populations (Moldakhmetova *et al*., 2022; Shimelkova *et al*., 2020).

The *A.m.carnica* breed is throughout the territory of Kazakhstan in six climate zones: Desert, semi-desert, steppe, forest-steppe, foothill, and mountain. The composition and distribution of bioecological properties of honey-bearing resources depend on the geographical features of their habitat zone. Therefore, beekeepers note that bee productivity depends on latitude, terrain, and altitude above sea level. At the same time, it is believed that the same plants in different geographical zones secrete nectar in different quantities and quality (Samsonova and Sidorenko, 2022) and due to the habitat climate variations of the honey bee, the search for factors of primary importance for it is of particular interest (Shklyaev and Shklyaeva, 2011; Korzh and Kiryushin, 2012).

One of the important factors for honey bees is the air temperature and relative humidity. Temperature fluctuations inside the nest have a strong influence on the duration and course of development of worker bees, queens, and drones. The temperature factor affects all biological objects, so honey bees become resistant to low temperatures in a cold climate zone as they lower the free water percentage in their body, slow the metabolic processes, and lower the activity of the endocrine glands (Lipatov, 2012). The nectar productivity of plants is closely related to air temperature, light level, air humidity, soil structure, soil fertility, and age (Proskuryakov, 2007). Relative humidity determines the possibility of active flight, but its indirect effect, primarily through nectar, is even more important. Its thickening under the influence of high temperature deprives bees of the necessary feed (Korzh, 2012), while during the active period of family life, the air humidity in the bee dwelling depends on some factors. Among them are the humidity of the outside air, the moisture content in the feed, the degree of activity of bees, and the number of broods in the nest. In summer, the relative humidity in various areas of the bee habitat ranges from 25-100%. The minimum values of relative humidity are typical for periods with low external temperature and the maximum values are for high temperature and humidity (Korzh, 2012).

The success of the flight activity of bees is highly dependent on external conditions. In conditions of optimal climate parameters, the flowers' visit of bees depends on the amount of nectar released. In cloudy weather, the indicators of nectar productivity decrease somewhat due to a sharp reduction in the sunshine duration and changes in temperature and humidity (Pankov, 2008).

Agreeing with the available literature data, it should be noted that factors affecting honey productivity such as air temperature and relative humidity also depend on the climate zones of bee breeding.

We aimed to study the effect of the climate zones of Kazakhstan on the morphometric parameters of *Apis mellifera carnica* bees.

Material and Methods

Ethical Approval

The protocol of the study was discussed and approved at the meeting of the local ethical committee of the Kazakh Research Institute of Animal Husbandry and Feed Production on November 07, 2022. The study of morphometric traits of bees was carried out after the death of bees. Not a single bee was injured during the work.

Table 1: Temperature and precipitation of climate zones of Kazakhstan

Climate zones	Temperature	Precipitation amount (mm)
Deserted	+12°C-17°C	2.9
Semi-desert	+11°C-23°C	1.6
Mountain	+14°C-27°C	46.0
Foothill	+6°C-19°C	38.0
Steppe	+11°C-25°C	30.1
Forest-steppe	+13°C-20°C	34,4.0

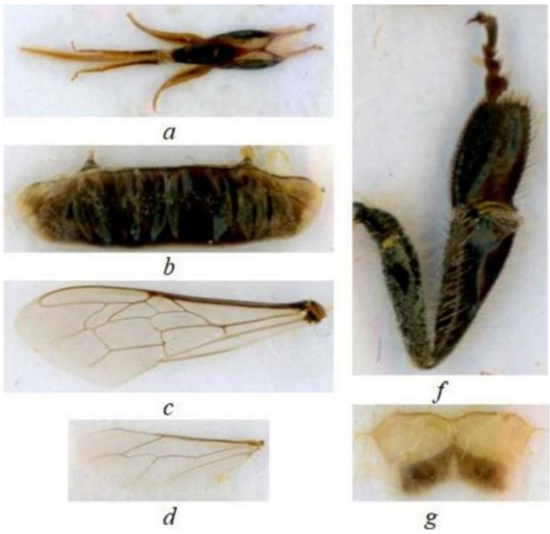

Fig. 1: Exterior indicators; (a) Proboscis; (b) Tergite; (c) Anterior wing; (d) Anterior small wing; (f) Hind leg; (g) Sternite

Location and Period of the Study

Bee samples for the study were selected during the period of full-fledged activity of bees in the autumn before winter in 2022. Mostly the selected bees were bred during the active honey harvest and in September. Preparation, measurement, and biometric processing of exterior signs of bees were carried out in the laboratory of LLP "Kazakh Scientific Research Institute of Animal Husbandry and Feed Production" in Almaty, Kazakhstan.

In total, ten bee colonies of the *A.m. carnica* breed from six bee farms were selected for research, from six climate zones: Desert, semi-desert, steppe, forest-steppe, foothill and mountain and different regions: Southern, northern, eastern, western Kazakhstan (Table 1).

Sample Collection and Analysis

During the period of full activity, 30 samples of the right front wings, legs, proboscis, hooks, sternite, and tergite were taken from each bee family (Fig. 1). Samples were fixed with ethyl alcohol on a transparent adhesive tape, scanned and received an electronic version and each batch was labeled indicating the numbers of the bee family. Morphometric parameters were analyzed using a Levenhuk MED D35T liquid crystal microscope (China). Scanning was performed using an Epson V600 Photo (Indonesia), while the image resolution was 3200 dots per inch (image size: 5782×3946 pixels).

To conduct a comparative analysis of the morphological characteristics of bees living in different climate zones of the republic, measurements were carried out according to the Cubital (Ci) and dumbbell (Hi) indices, as well as the discoidal Displacement (DsA) of the wings determined by the morphometric method according to Kartashev A.

Statistical Analysis

The obtained experimental material was processed in the Microsoft Excel program supplemented with the XLStat analytical application by methods of variational statistics (variational series, arithmetic mean, arithmetic mean error, Coefficient of Variation (CV), correlation coefficient).

Results

Morphometric Characteristics of Bees

The conducted studies have shown that the highest value of the cubital index was found in bees living in the semi-desert zone compared to the cubital index of bees living in the steppe, foothill, and mountain zones (Table 2).

The highest dumbbell index was found in bees of the semi-desert, but no significant differences were recorded between bees of other habitats (Fig. 2). Bees of the semi-desert distinguished themselves by discoidal displacement. A significant ($p<0.05$) difference was established between the indicators of this trait in bees in forest-steppe, foothill, and mountain zones (Table 2).

Results of External Indicators of Worker Bees

It is known that the exterior of a biological organism depends on its habitat. It is the habitat that determines the phenotype by which their industrial purpose can be judged. Therefore, to study the exterior characteristics of the *A.m. carnica* breeds bees bred in various climate zones, 11 morphological characteristic data were determined (Table 1A).

The studied bee population was divided into four groups based on the analysis of the exterior characteristics. The first Group (G1) included bees bred in the foothill zone. These bees had the highest of the exterior along the length of the proboscis and the length and width of the sternite. The length of the proboscis of bees exceeded the indicator of this trait in bees in the desert, semi-desert, steppe, and forest-steppe zones. The length and width of the sternite significantly ($p<0.05$) exceeded the indicator of bees in the desert, steppe, and forest-steppe zones.

The second (G2) included bees of the steppe zone, which differed in the number of hooks, the length and width of the tergite, and the length and width of the wax mirror. A significant ($p<0.05$) difference was established between the indicators of bees bred in all natural and climate zones. There was no difference in the length and width of the tergite between the semi-desert and forest-steppe zones and there was no significant difference in the width and length of the wax mirror of the desert and semi-desert zones.

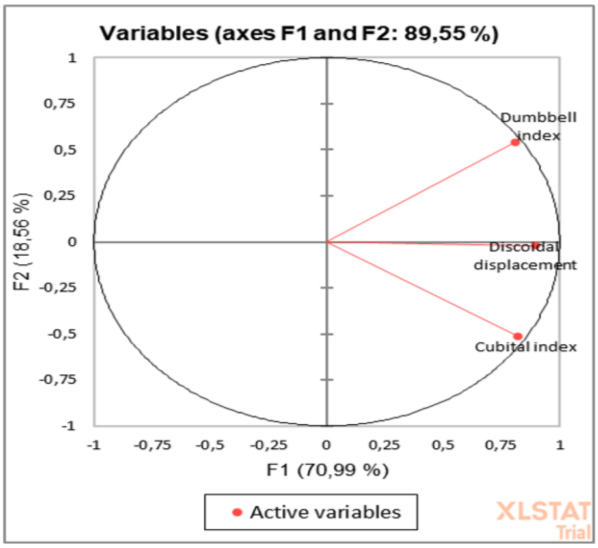

Fig 2: Correlation circle (or variables chart) morphometric characteristics of bees of the *A.m. arnica*

Table 2: Morphometric characteristics of bees of the *A.m. carnica* breed in the context of climate zones

Climate zone	Colonies n	Ci M ± m	Ci CV	Hi M ± m	Hi CV	DsA M ± m	DsA CV
Desert	10	2,78±0,06	6,33	1,08±0,01	4,25	3,91±0,25	-
Semi-desert	10	2,90±0,06	6,24	1,09±0,01	2,65	4,23±0,18	-
Steppe	10	2,71±0,07	8,46	1,06±0,01	2,71	4,06±0,29	-
Forest-steppe	10	2,80±0,09	9,91	1,07±0,02	5,32	3,5±0,46	-
Foothill	10	2,66±0,04	4,66	1,08±0,01	4,12	3,84±0,16	-
Mountain	10	2,78±0,05	6,12	1,08±0,01	3,98	3,71±0,14	-

*Ci-cubital index, Hi-dumbbell index, DsA-discoidal displacement

The third (G3) included bees in the mountain zone with the highest temperature and precipitation values (Table 1), distinguished by the development of the tarsal index. Their average significantly ($p<0.05$) exceeded those of all other bees living in other natural and climate zones.

The fourth (G4) includes bees of the forest-steppe zone, which have the highest average of the length and width of the right wing and significantly ($p<0.05$) exceed the value of other groups.

Thus, results showed the bees' ability to adapt to various climate zone conditions and the acquired abilities can be inherited in the future, which will allow the creation of new ecotypes through breeding work.

Discussion

Available research studies stated the scientific and practical interest regarding bees' impact on ecosystems and in the cross-pollination of crops (Oliver, 2014; Danner *et al*., 2017; Doublet *et al*., 2017). The birthplace of the *A.m. carnica* breed is the southeastern part of the high-altitude climate of the Alps (Meixner *et al*., 2013). This breed has developed and spread to other parts of the climate and their exterior and constitutional characteristics have begun to change somewhat, under the influence of the habitat of natural and climate zones.

The Kazakh population of honey bees of the *A.m. carnica* breed is currently being bred in six natural and climate zones of Kazakhstan (Limanskaya *et al*., 2021). Alpatov proposed to use only one cubital index for the assessment and identification of bees (Janczyk and Tofilski, 2021), while other scientists published that for a complete assessment, it is necessary to use all three listed indices and the tarsal index (Ilyasov, 2016).

Our results on the breed affiliation determination by three indices were confirmed by other studies which established that the breed can be determined by the cubital index together with the discoidal displacement. Such studies determined the main informative morphometric indicators: The length of the trunk, the length and width of the wax mirror, and the front wing and its venation, based on which it is possible to determine three indices used in determining the level of the pedigree of honey bees (Ilyasov, 2016).

The morphometric analysis allows us to determine the influence of macroclimate conditions on the changes in some exterior indicators of honey bees (Franck *et al*., 2000; Cauia *et al*., 2008). Obtained results showed that t the wing indices (Ci, Hi, DsA) are within the range accepted for the breed *A.m. carnica* (Ruttner, 2006). The indices of the anterior right wing in honey bees bred in the semi-desert zone were higher than in bees bred in the other five zones.

It should be noted that the size of the front right wing is influenced by the habitat of climate zones. The wing length ranges from 8.97 in the mountainous and 9.79 in the forest-steppe zones, while the wing width ranges from 3-3.56. Bees bred in the forest-steppe zone have better-developed wings compared to the mountain and semi-desert zones in width by 18.70% in length -9.14%, which showed the best flight abilities of bees in the forest-steppe zone.

The morphological characteristics of the studied experimental bees correspond to the standards of the *Carniolan (Apis mellifera carnica pollm)* and *Carpathian* (*Apis mellifera carpatica*) breeds: The tarsal index is 57.2%, the proboscis length was 6.45 mm, respectively, among the Carpathian bee breeds 48.62, 55.96, 6.7 mm (Kakhramanov *et al*., 2021). Length and width means of forewings were 9.007 ± 0.04 mm and 3.16 ± 0.015 mm respectively in Iran. Also, the cubital index and proboscis length means were 2.41 ± 0.03 and 6.5 ± 0.01 respectively (Gomeh *et al*., 2016).

Thus, based on the results, the Kazakh population of *A.m. carnica* honey bees is fully acclimatized to all climate zones of Kazakhstan. The influence of the habitat on the zones of the country is noted. For example, bees bred in the semi-desert zone of Kazakhstan are constitutional indicators: In proboscis length, length, and width of the wing, the best bees are in the forest-steppe zone

Kazakhstan's population of *A.m. carnica* honey bees can be used as a zoned breed in all climate zones of Kazakhstan in the future. In this regard, the populations of the *A.m. carnica* breed formed in semi-desert zones can be taken as the basis of the gene pool of breeding groups for further distribution, to create a new ecotype with high indices of the right front wing.

Conclusion

According to the results obtained, the bee population was divided into four zones. The highest proboscis length and sternite length and width were found in the foothill habitat zone. The highest width and length of the tergite, the length and width of the wax mirror, and the number of hooks were in the steppe zone. The tarsal index was developed in bees living in the mountain zone and the length and width of the right wing were developed in bees living in the forest-steppe zone. The directions of further research, on the one hand, can be focused on the creation of new ecotypes of bees through breeding work, on the other hand, on the development of recommendations for beekeeping farms in Kazakhstan, depending on the type of climate zone, to improve the efficiency of beekeeping.

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Author’s Contributions

All authors equally contributed to this study.

Ethics

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Table 1A: Results of external indicators of worker bees in different climate zones of Kazakhstan (n = 30)

Morphometric indicators	Bee farm 1 Desert		Bee farm 2 Semi-desert		Bee farm 3 Steppe		Bee farm 4 Forest - steppe		Bee farm 5 Foothill		Bee farm 6 Mountain	
	M ± m	CV	M ± m	CV	M±m	CV	M ± m	CV	M ± m	CV	M ± m	CV
Proboscis length	6,18±0,06	5,36	6,19±0,05	1,11	6,19±0,06	5,05	6,23±0,08	6,75	6,29±0,02	1,87	6,26±0,03	2,99
Number of leads	21,20±0,22	5,73	20,0±2,01	14,14	21,67±0,18	4,59	19,93±0,23	6,31	20,50±0,42	11,22	19,43±0,53	14,89
Tergite length	2,04±0,02	4,59	2,01±0,03	2,01	2,19±0,02	4,31	2,05±0,06	4,27	2,20±0,01	3,70	2,14±0,01	2,60
Tergite width	4,78±0,03	0,08	4,81±0,03	0,82	4,85±0,06	6,31	4,26±0,08	2,95	4,79±0,02	2,51	4,63±0,03	3,43
Sternite length	2,74±0,01	2,85	2,77±0,09	4,52	2,73±0,01	2,43	2,72±0,04	2,14	2,83±0,03	5,75	2,81±0,02	3,46
Width of sternite	3,99±0,02	3,21	4,02±0,11	3,86	4,23±0,02	2,98	4,18±0,03	0,88	4,65±0,03	3,26	4,40±0,02	2,20
Length of the wax mirror	1,46±0,01	5,08	1,45±0,01	0,34	1,48±0,01	3,47	1,41±0,05	5,13	1,27±0,01	4,74	1,21±0,01	4,05
Width of the wax mirror	2,31±0,02	4,64	2,25±0,09	5,77	2,32±0,02	4,44	2,24±0,02	1,48	2,28±0,02	5,02	2,13±0,02	4,32
Tarsal index	57,09±0,56	5,42	55,65±0,95	2,43	52,98±1,27	13,19	57,77±0,11	0,26	57,52±0,55	5,23	58,77±0,57	5,32
Right-wing length	9,33±0,03	1,77	9,2±0,16	2,52	9,31±0,03	1,68	9,79±0,05	3,04	9,14±0,04	2,39	8,97±0,03	1,64
Width of the right-wing	3,08±0,01	2,28	2,99±0,03	1,32	3,16±0,03	5,19	3,56±0,03	4,81	3,24±0,02	3,28	3,19±0,01	2,38

*M ± m-Arithmetic mean and arithmetic mean error; CV-Coefficient of Variation