



UWS Academic Portal

A spotlight on the Egyptian honeybee (*Apis mellifera lamarckii*)

El-Seedi, Hesham R.; El-Wahed, Aida A. Abd; Zhao, Chao; Saeed, Aamer; Zou, Xiaobo; Guo, Zhiming; Hegazi, Ahmed G.; Shehata, Awad A.; El-Seedi, Haged H. R.; Algethami, Ahmed F.; Alnaggar, Yahya; Agamy, Neveen F.; Rateb, Mostafa E.; Ramadan, Mohamed F. A.; Khalifa, Shaden A. M.; Wang, Kai

Published in:
Animals

DOI:
[10.3390/ani12202749](https://doi.org/10.3390/ani12202749)

Published: 13/10/2022

Document Version
Publisher's PDF, also known as Version of record

[Link to publication on the UWS Academic Portal](#)

Citation for published version (APA):
El-Seedi, H. R., El-Wahed, A. A. A., Zhao, C., Saeed, A., Zou, X., Guo, Z., Hegazi, A. G., Shehata, A. A., El-Seedi, H. H. R., Algethami, A. F., Alnaggar, Y., Agamy, N. F., Rateb, M. E., Ramadan, M. F. A., Khalifa, S. A. M., & Wang, K. (2022). A spotlight on the Egyptian honeybee (*Apis mellifera lamarckii*). *Animals*, 12(20), [2749]. <https://doi.org/10.3390/ani12202749>

General rights









Copyright and moral rights for the publications made accessible in the UWS Academic Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact pure@uws.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

Review

A Spotlight on the Egyptian Honeybee (*Apis mellifera lamarckii*)

Hesham R. El-Seedi ^{1,2,3,4,*}, Aida A. Abd El-Wahed ⁵ , Chao Zhao ⁶ , Aamer Saeed ⁷, Xiaobo Zou ⁸, Zhiming Guo ⁸ , Ahmed G. Hegazi ⁹ , Awad A. Shehata ^{10,11,12} , Haged H. R. El-Seedi ¹³, Ahmed F. Algethami ¹⁴, Yahya Al Naggar ¹⁵ , Neveen F. Agamy ¹⁶, Mostafa E. Rateb ¹⁷ , Mohamed F. A. Ramadan ¹⁸ , Shaden A. M. Khalifa ^{19,*} and Kai Wang ²⁰ 

- ¹ International Research Center for Food Nutrition and Safety, Jiangsu University, Zhenjiang 212013, China
- ² Pharmacognosy Group, Department of Pharmaceutical Biosciences, Biomedical Centre, Uppsala University, P.O. Box 591, SE-751 24 Uppsala, Sweden
- ³ Department of Chemistry, Faculty of Science, Menoufia University, Shebin El-Koom 32512, Egypt
- ⁴ International Joint Research Laboratory of Intelligent Agriculture and Agri-Products Processing, Jiangsu Education Department, Nanjing 210024, China
- ⁵ Department of Bee Research, Plant Protection Research Institute, Agricultural Research Centre, Giza 12627, Egypt
- ⁶ College of Marine Sciences, Fujian Agriculture and Forestry University, Fuzhou 350002, China
- ⁷ Department of Chemistry, Quaid-i-Azam University, Islamabad 45320, Pakistan
- ⁸ School of Food and Biological Engineering, Jiangsu University, Zhenjiang 212013, China
- ⁹ Zoonotic Diseases Department, National Research Centre, Giza 12622, Egypt
- ¹⁰ Avian and Rabbit Diseases Department, Faculty of Veterinary Medicine, University of Sadat City, Menoufia 22857, Egypt
- ¹¹ PerNaturam GmbH, An der Trift 8, 56290 Gördenroth, Germany
- ¹² Prophy-Institute for Applied Prophylaxis, 59159 Bönen, Germany
- ¹³ Faculty of Medicine, Riga Stradins University (RSU), LV-1007 Riga, Latvia
- ¹⁴ Alnahal Aljwal Foundation Saudi Arabia, P.O. Box 617, Makkah 24211, Saudi Arabia
- ¹⁵ Zoology Department, Faculty of Science, Tanta University, Tanta 31527, Egypt
- ¹⁶ Nutrition Department, Food Analysis Division, High Institute of Public Health, Alexandria University, Alexandria 21561, Egypt
- ¹⁷ School of Computing, Engineering and Physical Sciences, University of the West of Scotland, Paisley PA1 2BE, UK
- ¹⁸ Central Agriculture Pesticides Laboratory, Pesticide Analysis Research Department, Agriculture Research Center, Giza 24221, Egypt
- ¹⁹ Department of Molecular Biosciences, The Wenner-Gren Institute, Stockholm University, SE-106 91 Stockholm, Sweden
- ²⁰ Institute of Apicultural Research, Chinese Academy of Agricultural Sciences, Beijing 100093, China
- * Correspondence: hesham.el-seedi@farmbio.uu.se (H.R.E.-S.); shaden.khalifa@regionstockholm.se (S.A.M.K.); Tel.: +46-700-43-43-43 (H.R.E.-S.)



Citation: El-Seedi, H.R.; El-Wahed, A.A.A.; Zhao, C.; Saeed, A.; Zou, X.; Guo, Z.; Hegazi, A.G.; Shehata, A.A.; El-Seedi, H.H.R.; Algethami, A.F.; et al. A Spotlight on the Egyptian Honeybee (*Apis mellifera lamarckii*). *Animals* **2022**, *12*, 2749. <https://doi.org/10.3390/ani12202749>

Academic Editors: María Shantal Rodríguez-Flores, Olga Escuredo and M. Carmen Seijo

Received: 30 July 2022

Accepted: 27 September 2022

Published: 13 October 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Simple Summary: The Egyptian honeybee (*Apis mellifera lamarckii*) is one of the honeybee subspecies known for centuries since the ancient Egypt civilization. The subspecies of the Egyptian honeybee is distinguished by certain traits of appearance and behavior that were well-adapted to the environment and unique in a way that it is resistant to bee diseases, such as the Varroa disease. The subspecies is different than those found in Europe and is native to southern Egypt. Therefore, a special care should be paid to the vulnerable *A. m. lamarckii* subspecies and greater knowledge about the risk factors as well as conservation techniques will protect these bees. Additionally, more qualitative and quantitative measures will be taken to obtain deep insights into the *A. m. lamarckii* products' chemical profile and biological characters.

Abstract: Egypt has an ongoing long history with beekeeping, which started with the ancient Egyptians making various reliefs and inscriptions of beekeeping on their tombs and temples. The Egyptian honeybee (*Apis mellifera lamarckii*) is an authentic Egyptian honeybee subspecies utilized in apiculture. *A. m. lamarckii* is a distinct honeybee subspecies that has a particular body color, size, and high levels of hygienic behavior. Additionally, it has distinctive characteristics; including the presence

of the half-queens, an excessive number of swarm cells, high adaptability to climatic conditions, good resistance to specific bee diseases, including the *Varro disorder*, and continuous breeding during the whole year despite low productivity, using very little propolis, and tending to abscond readily. This review discusses the history of beekeeping in Egypt and its current situation in addition to its morphology, genetic analysis, and distinctive characters, and the defensive behaviors of native *A. m. lamarckii* subspecies.

Keywords: beekeeping; beehives; Egyptian honeybee (*Apis mellifera lamarckii*); genetic analysis; defensive behaviors

1. Introduction

Beekeeping has been conducted for thousands of years; hence, the honeybee and their products have been known in ancient Egypt. Egyptians used bee products in daily life, including honey and wax, as food and in ceremonies. They also recorded their knowledge and practices on templates and tombs [1,2].

The honeybee subspecies *Apis mellifera lamarckii* is assumed to be the same species as the one discovered during the Pharaohs' period [3,4]. *A. m. lamarckii* Cockerell, 1906 is geographically distributed in the Egyptian desert, delta region, Nile valley, and Sudan [5–7]. Lamarck's honeybee was previously known as *Apis fasciata* Latreille and is considered an offshoot of *adansonii*. It resembles the lighter, yellow-banded varieties with very dark drones, and the width of the worker cells is identical to that of *adansonii* from center to center [7]. Lamarck's bee is described as a good housekeeper but a poor honey producer. Thus, the Carniolan honeybee, which gained popularity because it is peaceful and easy to manage in modern Langstroth hives, thus effectively replaced the *A. m. lamarckii* in commercial beekeeping in Egypt.

As a result, the native honeybee population in Egypt was suppressed and predominantly centered in the Manfalut area of the Assiut governorate, which was surrounded by hybrids from Europe. *A. m. lamarckii* was introduced to the Dakhla oasis in 1928, and was utilized there until 1960, when the New Valley Government decided to breed less aggressive bees than *A. m. lamarckii* [8,9]. A large number of *A. m. lamarckii* colonies (about 400,000) were found in traditional mud-tube hives in the Assiut Governorate and small populations in isolated oases of Egypt [10]. The *A. m. Lamarckii* is noticeably smaller and has legs and wings that are shorter. Compared to the European subspecies, its colonies have fewer bees. It does not store food for the winter or form winter clusters, and it does not stop reproducing for practically the entire year. It is viewed as a representative model of the tropical African bees in general [11].

The phylogenetic analyses of *A. m. lamarckii* and other subspecies demonstrated a close relationship between *A. m. lamarckii* and *A. m. syriaca* (Syrian honeybee) [12]. *A. m. lamarckii* has various distinctive characteristics, including a higher quality of reared queens [10], *A. m. lamarckii* exerts high levels of defensive behavior [13]. The Egyptian honeybee exhibits a more combative defensive response when compared to European bees, and the *A. m. lamarckii* larva develops more quickly; hence, they tolerate *Varroa destructor mites*, the serious and dangerous pest to *Apis mellifera* species [9]. Additionally, the biochemical and molecular characterization for three subspecies of honey bee workers explained the high genetic gap of 0.25 separating the Egyptian *A. m. lamarckii* subspecies from the other two subspecies, *A. m. ligustica* (Italian), and *A. m. carnica* (Carniolan) [14]. Here, we aimed to shed the light on the history of beekeeping in Egypt and the Egyptian honeybee subspecies *A. m. lamarckii*, reviewing their morphology, genetic analysis, distinctive characters, and defensive behaviors as part of our efforts to study honeybee and its bee products [15–24].

2. The History of Beekeeping in Egypt and Its Current Situation

Honey is a natural product produced by bees and used in Egypt not only as a sweetener but also associated with medical practices, and was deemed a poison for ghosts, demons, evil spirits, and the dead, representing a symbol of resurrection [25]. The first crude examples of the honeybee hieroglyphs were carved by the Egyptians of the first dynasty, in approximately 3000 B.C.E [2–4,26]. In the Nile Valley region, the bees were used as a source of honey from the earliest years; thus, bees were highly appreciated insects by the ancient Egyptians. In the old kingdom, the earliest inscription exemplifying beekeeping came from the sun temple of pharaoh Newossere in the fifth dynasty and back to 2450 B.C.E. [27]. In the sun temple, a room adjacent to the central obelisk was discovered by Ludwig Borchardt in 1898 and called “The Chamber of the Seasons” as it contains reliefs of activities that happened at particular times of the year, and one of them was found to be the oldest evidence of beekeeping [1,27]. The bas-relief from left to right shows four scenes: (I) a beekeeper working with the beehives; (II) three men pouring honey into containers; (III) two men processing honey (this scene is mostly missing); (IV) a beekeeper sealing honey in a vessel for storage [1]. By the end of the old kingdom and during the sixth dynasty, honey production increased to the level of trading [26]. During the time of the new kingdom, there were many tombs with images illustrating the practices involved in the treatment using bees and their products [28]. In the tomb of the 18th Dynasty vizier Rekhmire, there were inscriptions demonstrating honeycombs gathering from large horizontal hives, as shown in Figure 1, pouring the honey into large vessels, the successive honey sealing in diamond-shaped containers, and comb pulverizing [1]. During the 26th dynasty, the tomb of Pabasa demonstrated one of the most famous beekeeping reliefs in Egypt, where a beekeeper is facing a group of honeybee and a series of horizontal hives with his hands held up in praise. These horizontal hives were similar to the carved hives of the old kingdom from Newossere Any’s sun temple, as shown in Figure 2. They also authenticated the continued value of the honey and the honeybee in the ancient Egyptian times and the progress of hives types throughout the time [1,29,30].



Figure 1. Honey combs gathering from large horizontal hives in Rekhmira tomb.



Figure 2. Beekeeping reliefs from the tomb of Pabasa and Karnak Temple (Photography by Aida Abd El-Wahed).

In the Ptolemaic Period (304–30 B.C.E.), the state taxed bee keeping and the bee derived products. In the Nile Valley, beekeeping processes and breeding programs were established, as honey was fundamental to the people's food [25]. The Egyptian mud hives (traditional bee hives) were placed in piles that could reach hundreds and were combined by pouring mortar in-between [31,32]. In 1918, modern beekeeping started in Egypt using wooden Langstroth frames. In 1920, the first association of beekeepers was established to improve beekeeping process and develop its marketing. Since, then traditional beekeeping methods were used in parallel with modern ones.

The modern beekeeping represents 99% of the used practices in Egypt [9]. Figure 3 illustrates the difference between the Egyptian mud traditional hives (A1-3) and the modern wooden ones (B). According to the Food and Agriculture Organization (FAO), statistics on the number of beehives in Egypt between 1961–2020 have been fluctuating, as represented in Figure 4. The number of beehives demonstrated noticeable increases between 1964–1972, 1980–1990, and 1999–2001, reaching 937,000, 1,651,000, and 1,485,000 hives, respectively, at the end of each period. In contrast, they demonstrated noticeable decreases in 1980, 1994, and 2017, reaching 858,000, 1,225,000, and 820,516 hives, respectively [9].

Honey bees are given special attention in Egypt because of their importance in pollination and their impact on the economy [33]. The pollination is mainly conducted using the Egyptian clover blooming during June, cotton flowering during August–September, and a minor contribution of citrus in April [31,32]. In the future, thermal stress on the Egyptian honey bee colonies will be a significant problem for beekeepers, especially during summer [24,34].



Figure 3. The Egyptian mud traditional hives (A1–A3) and modern ones (B). (Photo A1–A3: Dahy M. Mostafa and used with permission).

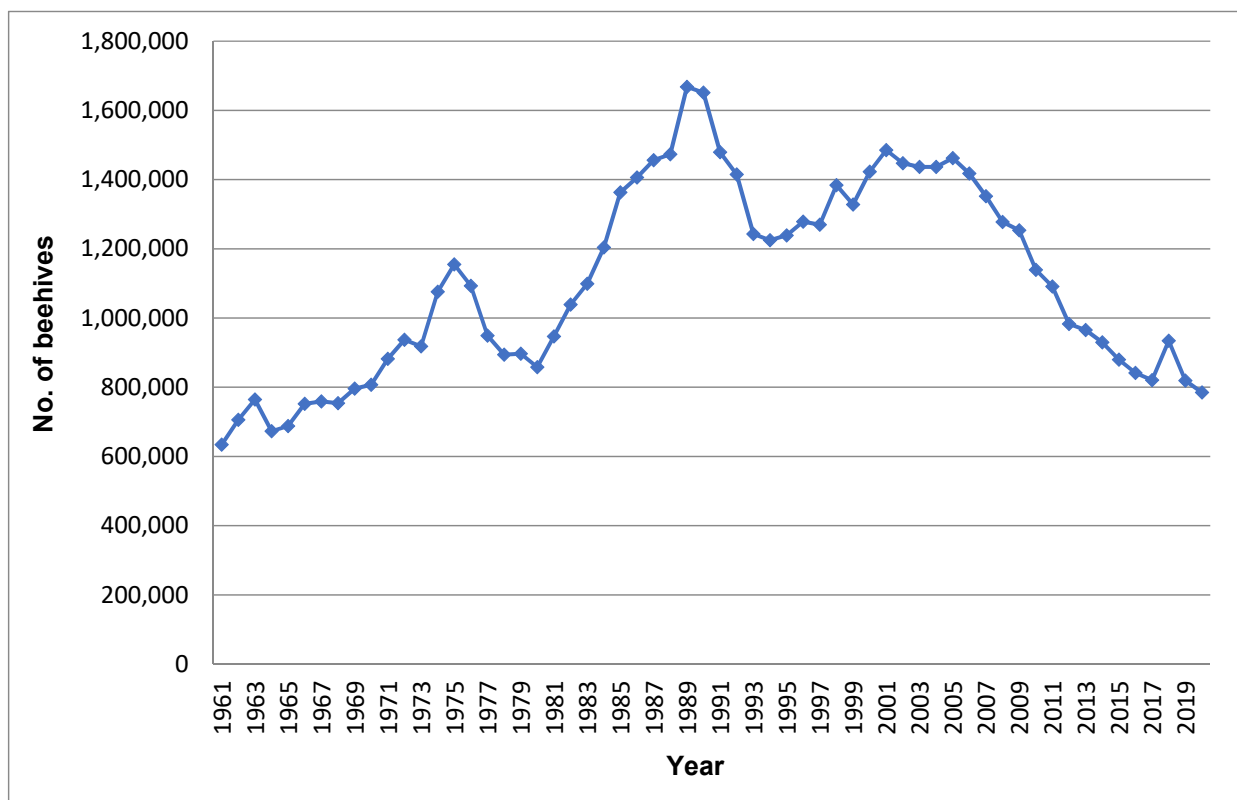


Figure 4. Beehives stocks in Egypt within the period (1961–2020) according to FAO (Data source: www.fao.org/faostat/en/#data/QCL, accessed on 29 July 2022).

3. *Apis mellifera lamarckii* Morphology

The Egyptian *A. m. lamarckii* is considered an offshoot of *adansonii*. [7]. Some morphometric characteristics of Egyptian *A. m. lamarckii*, African *Apis mellifera scutellata*, and *Apis mellifera jemenitica* were reported where these subspecies were very close to *A. m. lamarckii*, as mentioned in Table 1, using different techniques such as an electron microscope [7,11,35–39]. Otherwise, the average length of the honeybee forewing in difference races was reported. The highest average was 10.700 mm in *A. m. florea*, while the lowest average was 8.275 mm in *A. m. lamarckii*. The average head length on different races in adult gave the highest average of 5.575 mm in *A. m. lamarckii*, while the lowest average was 3.750 mm in *A. mellifera ligustica* [38]. The mean body mass of the European (*Apis mellifera Carnica*) bee amounted to 120 mg, while the Egyptian bee to 78 mg. This shows that the Egyptian bee is much smaller than the European one, with only 65% of its mass. Similar results related to the thorax masses of both subspecies differ significantly (33 mg vs. 24 mg) for the European and Egyptian bee, respectively. The Egyptian bee is characterized with shorter wing size (45 mm) compared to the European bee (55 mm). The Egyptian honeybee *A. m. lamarckii* is significantly smaller, slimmer, and has shorter wings and legs. Moreover, the wing load was 17 and 21 Nm⁻² for the Egyptian and European bee, respectively [11].

Table 1. Morphological characters of *Apis mellifera lamarckii* compared to African *Apis mellifera scutellata* and *Apis mellifera jemenitica*.

Morphology Characteristics	<i>Apis mellifera lamarckii</i>	African <i>Apis mellifera scutellata</i>	<i>Apis mellifera jemenitica</i>	Reference
Color	Lighter yellow-banded varieties with very dark drones	-	-	[7]
Width of worker cells	4.8 mm	-	-	[7]
Average head width	4.550 mm	-	-	[37]
Bodyweight	78 mg	-	87.65 mg	[11,40]
Body size	56.82 mm	55.04 mm	54.07 mm	[41]
Thorax mass	24 mg	-	-	[11]
Wing load	17 Nm ⁻²	-	-	[11]
Wing size	45 mm ²	-	-	[11]
Average length of forewing	5.575 mm	-	-	[37]
Forewing width	2.78–2.96 mm	2.71–3.03 mm	2.44, 3.20–3.03 and 2.77–3.23 mm	[35,36,42–44]
Leg size	7.39 mm	-	-	[36]
Forewing length	8.23 and 8.74 mm	8.48–9.01 mm	7.94, 7.53–9.01, 7.94, and 7.55–9.39 mm	[35,36,40,42–46]
Tongue length	5.75 mm	-	-	[35]
Hindwing length	6.11 mm	4.02–4.24 mm	5.85 mm	[35,40–42,45]
Hindwing width	1.76 mm	1.52–1.68 mm	1.67 mm	[35,42]
Femur length	2.24 mm	2.44–1.63 mm	2.44, 2.39–1.63 mm	[35,42,43]
Tibia length	2.82 mm	3.05–3.23 mm	2.55, 2.69–3.23 mm	[35,40,42,43]
Tibia width	-	-	1.12 mm	[40]
Basitarsus length	2.13 mm	1.81–2.02 mm	-	[35,42]
Basitarsus width	1.10 mm	1.05–1.15 mm	-	[35,42]
Cubital index	2.33 and 2.94 mm	1.77–2.86 & 2.33 mm	2.10–2.86 and 2.36 mm	[35,41–43,46]
Number of hooks	20.34	-	-	[35]
Lengths of the workers flagella	2.60–2.80 mm	-	2.29–2.80 mm	[38,43]
Lengths of the queens flagella	2.60 mm	-	-	[38]
Lengths of the half-queen flagella	2.48–2.60 mm	-	-	[38]

Table 1. Cont.

Morphology Characteristics	<i>Apis mellifera lamarckii</i>	African <i>Apis mellifera scutellata</i>	<i>Apis mellifera jemenitica</i>	Reference
Length waxmirror	1.11 mm	1.16–1.32 mm	-	[36,42]
Waxmirror index	0.55 mm	-	-	[36]
Hair length	21.49 mm	20.88 mm	22.55 mm	[41]
Length of hind leg	738.09 mm	741.10 mm	717.71 mm	[41,43]
Wing angle J16	98.42	-	-	[41]
Proboscis length	5.65–570 mm	-	5.28, 5.30 and 4.84–5.74 mm	[40,43,45]
Metatarsus length	1.88–1.91 mm	-	2.03, 2.22 and 1.94–2.26 mm	[40,43,45]
Metatarsus width	1.05–1.08 mm	-	1.10, 1.01 and 0.97–1.16 mm	[40,43,45]
Wax mirror width	-	-	2.00 mm	[43]
Total length of antenna	3.92 mm	-	3.64 mm	[40,45]

(-): No reported.

The Egyptian honeybee *A. m. lamarckii* neither forms winter clusters nor stores food for overwintering and breed nearly throughout the year. *A. m. lamarckii* is forced to form winter clusters and to store food for unfavorable periods [11].

4. Distinctive Characters of *Apis mellifera lamarckii*

The Egyptian *A. m. lamarckii* is known for its excessive large number of swarm cells, continuous breeding during throughout the whole year, low productivity using very little propolis, and proclivity to migrate, tending to migrate readily [7,11]. Its colonies include fewer bees (8000–10,000) compared to the European subspecies, which have more than 40,000 bees. *A. m. lamarckii* was found to exhibit a higher mass specific metabolism than the European *A. m. carnica*, and *A. m. lamarckii*, being more aggressive, active, and well adapted to its environment [11,47]. Another characteristic of *A. m. lamarckii* is the presence of half-queens, which are intermediate in morphology between queens and workers. They have a number of ovarioles that range between workers and queens, are possibly egg-laying workers, and help the queen's colony by contributing to egg laying. *A. m. lamarckii* flagella of workers were longer than those of queens and half-queens; however, they did not differ in the length of flagellum. [38,48]. A study has been conducted to evaluate the quality of reared queens produced from *A. m. carnica* (Carniolian honey bee), *A. m. ligustica* (Italian honey bee), and *A. m. lamarckii* colonies. The highest accepted percentage of *A. m. lamarckii*-grafted larvae was significantly higher than *A. m. ligustica*, where the acceptance % was (93.75, 87.2, and 62.5) in *A. m. carnica*, *A. m. lamarckii* and *A. m. ligustica*, respectively. The Egyptian and the Carniolian colonies have a higher quality of reared queens represented in the long queen cell size, heaviest virgin queen, large number of ovarioles, and large volume of spermatheca of the produced queens than that of the Italian honey bees [10]. On the other hand, *A. m. lamarckii* was more resistance to chalkbrood diseases, with an infestation average of 0.218 % after the three inoculations. In contrast, the Carniolian race (*A. m. carnica*) demonstrated a lower tolerance, with an infestation average of 0.844% [49].

5. Genetic Analysis of *Apis mellifera lamarckii*

Using various analytical tools and different approaches, *A. m. lamarckii* mtDNA sequences were analyzed for a better understanding of its phylogenetic relationships with other different subspecies as well as to detect the genetic characteristics of these bees. The phylogenetic analyses of *A. m. lamarckii* and other different subspecies demonstrated a close relationship between *A. m. lamarckii* and *A. m. capensis*, *A. m. intermissa*, *A. m. ligustica*, and *A. m. scutellata*. The highest identity percentage (95.78%) was between *A. m. lamarckii* and *A. m. syriaca*, whereas *A. m. lamarckii* were far from *A. florea*, *A. koschevnikovi*, *A. cerana japonica*, *A. laboriosa*, *A. nuluensis*, and *A. m. sahariensis* [12]. Another study confirmed the close phylogenetic relationship between *A. m. lamarckii* and *A. m. syriaca* using the complete mtDNA sequences [50]. The honeybee in the dry regions

of Sudan (desert, semi desert, and dry savannah) were genetically similar to *A. m. lamarckii* and *A. m. syriaca*, as both of them possess the O-lineage [51]. Abou-Shaara et. al. [52] confirmed a close genetic relationship between *A. m. lamarckii*, *A. m. jemenitica* (Arabian or Nubian honeybee), and *A. m. syriaca*. *A. m. lamarckii* was distinguished by the restriction of the Hinf-I enzyme from other honeybee subspecies using a PCR assay [53]. CO I/Hinf I was used not only to discriminate the mitochondrial “O” lineage but also as a diagnostic site for *A. m. lamarckii* [54]. The whole mitochondrial genome of the Egyptian *A. m. lamarckii* was examined and a 16,589 bp mitochondrial genome of *A. m. lamarckii* including 37 classical eukaryotic mitochondrial genes and an A + T-rich region were revealed. The arrangements and directions of the genes were identical to those of other *Apis* mitogenomes. All genes terminated with TAA, seven genes started with ATT, four with ATG, and two with ATA. Nine genes were encoded on the light strand and four on the heavy strand. The whole 22 tRNA genes had a cloverleaf structure that ranged from 66 to 80 bp. *A. m. lamarckii* is clustered with other *A. mellifera* subspecies in the phylogenetic tree [55]. A study has been conducted on two *Apis mellifera* (*A. m. lamarckii* and *A. m. carnica*) races as well as the hybrid and demonstrated the presence of clear genetic variations between *A. m. lamarckii* and *A. m. carnica*; the hybrid was closely related to the Carniolan (*A. m. carnica*) rather than to the *A. m. lamarckii* race. The higher resemblance between the Carniolan race and the hybrid suggested that the hybrid originated from Egyptian drones and Carniolan queens [56]. The genetic relationships and identical genetic characteristics between different African bee subspecies were investigated and demonstrated that *A. m. lamarckii* has the least genetic relationships with all other studied African bee subspecies (*A. m. scutellata*, *A. m. capensis*, *A. m. intermissa*, and *A. m. monticola*). While those of north and east Africa, namely, *A. m. intermissa* and *A. m. monticola*, exhibited less genetic similarity, the African subspecies *A. m. scutellata* demonstrated considerable genetic similarity and a tight evolutionary link to *A. m. capensis*. There were very few similarities and no close links among the bees from North Africa, *A. m. Intermissa*, and *A. m. Lamarckii* [57].

6. *Apis mellifera lamarckii* Hygienic Behaviors

The hygienic behavior of different honeybee species plays a critical role in the colony’s health of diverse honeybee races [58,59]. The hygienic behavior represents a behavioral defensive response of honeybee workers to uncap the wax covering of the brood cells, detect diseased brood, get rid of infected larvae or pupae, and inhibit the spreading of infective diseases [60,61]. Hygienic behaviors enable bees to resist parasitic mites (*Varroa destructor*) [60,62], American foulbrood (*Paenibacillus larvae*), and chalkbrood (*Ascosphaera apis*) among other infestations [63,64]. Hygienic behavior helps maintain the health of densely populated insect societies by limiting the horizontal transmission of pathogens and population growth of parasites [65]. Hygienic behavior relies on a limited set of genes linked to different regulation patterns associated with an over-expression of cytochrome P450 genes [66].

Native honeybee races (for example, *A. m. jemenitica* and *A. m. syriaca*) exhibited a certain degree of hygienic behavior compared to the exotic one, owing to its different genetic structure as well as its compatibility with local environmental conditions [67,68]. The *A. m. jemenitica* native race was significantly higher than that of the exotic one, *A. m. carnica*. The deformed mites, as a result of the grooming behavior, were also significantly higher in the colonies of the native race than those of exotic one [68]. Al-lam and Zakaria reported two defensive behavior mechanisms against the *Varroa* mite, namely the hygienic and grooming behaviors to minimize the parasitic threat. Moreover, the hygienic behavior of the Egyptian hybrid honeybee represented in cutting up *Varroa* mite bodies was related to treating the diseased colonies with black cumin oil or an oils mixture [69,70]. *A. m. lamarckii* are characterized by their high levels of defensive behaviors [13]. *A. m. lamarckii* colonies were found to exhibit higher levels of hygienic behavior compared to the Egyptian *A. m. carnica* colonies, according to a study conducted by Kamel and other collaborators [13]. The study demonstrated that, after 24 h, the dead broods

were totally removed from 42.9% of *A. m. lamarckii* colonies, while 0% of the Egyptian *A. m. carnica* colonies were free from the dead broods. After 48 h, 71.4% of *A. m. lamarckii* colonies were completely free from the killed broods, whereas 8.3% of the Carniolan hybrid *A. m. carnica* colonies cleaned all of the killed broods [13].

In a different study, the percentages of cleaned cells were determined at different times for the local *A. m. lamarckii* and the Carniolan hybrid colonies and demonstrated 32.2% and 15.5% after 6 h, 70.6% and 38.4% after 24 h, 83.8% and 46.7% after 30 h, and 93.4% and 64.4% after 48 h, for the local *A. m. lamarckii* and the Carniolan hybrid colonies, respectively [35]. Clearly, the results revealed that *A. m. lamarckii* has significantly higher levels of hygienic behaviors, which could be affecting the survival and efficiency of the whole honeybee colonies against the Varroa mite infestation [13,35,60,65].

7. Biological Properties of Bee Venom from *A. m. lamarckii*

The venom produced by the Egyptian honeybee has a biological activity and potential pharmacological effects owned to the peptides, enzymes, amino acids, and minerals contents. Bee venom possesses biological properties that are anticancer, anti-inflammatory, and antibacterial [71].

Global threats to human health and the environment are posed by methylmercury pollution. The etiology of Minamata sickness was determined to be caused by methylmercury, which is a particularly neurotoxic pollutant. The intake of seafood exposes people to methylmercury. Because methylmercury rapidly crosses the blood–brain barrier, it can have an impact on the neurological system [72]. *A. m. lamarckii* venom has an in vivo protective influence (apitherapy) against methyl mercury chloride-induced blood–brain barrier dysfunction and neurobehavioral toxicity [73].

As one of the most serious infectious illnesses affecting cattle, buffalo, swine, goats, and sheep, foot-and-mouth disease (FMD) is a major problem worldwide, as per its high transmissibility and related monetary and productive losses [74]. FMDV was treated with Egyptian bee venom. Bee venom injections administered daily for seven days to sick goats and guinea pigs resulted in a significant reduction in the viral load and a shorter treatment period [72].

The comparison between bee venom composition obtained from *A. m. lamarckii*, *A. m. carnica*, and the hybrid has been established, and demonstrated that the hybrid venom was more similar to *A. m. lamarckii* than *A. m. carnica*, reflecting the domination of *lamarckii* subspecies' genetic characters over those of *carnica* [75].

Hyaluronidase, the main allergen in bee venom, contains four different N-linked carbohydrate sites, and consists of 373 amino acid residues. The enzyme acts as an anti-inflammatory by causing hyaluronic acid break down in various tissues, allowing it to enter the tissue. Treatment with hyaluronidase was reported to prevent tumor cells from reaching lymph nodes in T cell lymphoma, and it may have important anticancer effects to stifle tumor growth [76,77]. Recently, Abdel-Monsef and colleagues purified and characterized hyaluronidase enzyme for the first time from Egyptian bee venom homogeneously using DEAE-cellulose and Sephacryl S-300 columns [78,79].

Phospholipase A2 (PLA2), the second-largest component of bee venom after melittin, is one of the most significant bee venom enzymes and might be regarded as one of its primary constituents. It is a lipolytic enzyme that hydrolyzes phospholipids at the sn-2-acyl linkage to release free fatty acids and lysophospholipids. PLA2 has a wide range of pharmacological properties, such as the ability to inhibit the growth of cancer cells and to have anti-inflammatory, hepatotoxic, and neuroprotective effects [80–82]. PLA2 enzyme was purified from *A. m. lamarckii* venom and displayed anti-coagulant and anti-platelet aggregation activities, making it a promising agent against clot formation [83].

Additionally, the bee venom of *A. m. lamarckii* can treat respiratory illnesses by improving the haematological and respiration parameters in the animal model [84].

8. Conclusions and Future Perspective

A. m. lamarckii honeybee subspecies is thought to be the same subspecies as the one that could be found during the Pharaohs' time, and it is still managed in mud-tube hives beside modern hives. The Egyptian *A. m. lamarckii* spreads in the Egyptian desert, delta region, Nile valley, and Sudan and resembles the lighter yellow-banded varieties with very dark drones. *A. m. lamarckii* is known for its excessive number of swarm cells, continuous breeding during the whole year, and low productivity, using very little propolis, and tends to migrate readily. *A. m. lamarckii* is characterized by higher mass-specific metabolism, presence of the half-queens, and high levels of defensive behaviors. The indigenous *A. m. lamarckii* subspecies have been hybridized with other introduced varieties, especially *A. m. carnica*; hence, pure subspecies have become very rare.

Due to the limited location and quantity of colonies in the small districts of Upper Egypt (Assiut), where it is kept in modern and mud tube hives, the populations of *A. m. lamarckii* have unfortunately suffered a significant decline. The owners of these Egyptian hives consider them a family heritage and refuse to accept governmental calls to rescue and enlarge them.

In order to maintain their colony stocks, beekeepers were compelled to purchase colonies of different subspecies, such as Italian and Carniolan honeybee. To date, the current status and the geographic variation of the *A. m. lamarckii* populations in Egypt have not been studied in-depth and thus the data available is limited.

Futureward, efforts are highly recommended by the government, public, and researchers to preserve *A. m. lamarckii*, requiring more knowledge on the harmful effects threatening this bee subspecies as well as its conservation strategies, such as phylogenetic studies as well as the genetic network analysis. Moreover, beekeeping developmental projects can contribute to the conservation of honeybee and their environment. Qualitative and quantitative comparative studies could be conducted on *A. m. lamarckii* and the other Egyptian bee subspecies regarding their different products and how to be improved. One possibility that could be applied to improve the genetic conservation of local breeds in Egypt is the creation of isolated mating sites for the reproduction of *A. m. lamarckii* in the future breeding program. Although the Wadi Al-Assiut Protectorate uses the preserve for a range of flora and animals, including the native honeybees subspecies *A. m. lamarckii*, the protectorate should continue to focus on increasing bee populations with the help of the governmental scientific and financial support.

Further studies should focus on studying the *A. m. lamarckii* behavior that could positively affect the survival, efficiency, and decrease the infestation.

Author Contributions: Conceptualization, H.R.E.-S. and S.A.M.K.; Writing of the original draft, H.R.E.-S., A.A.A.E.-W., H.H.R.E.-S. and S.A.M.K.; Revision and editing of the final version, C.Z., A.S., X.Z., Z.G., A.G.H., A.A.S., A.F.A., Y.A.N., N.F.A., M.E.R., M.F.A.R. and K.W.; Supervision, H.R.E.-S. and K.W. All authors have read and agreed to the published version of the manuscript.

Funding: El-Seedi, H.R thanks Jiangsu University for the Adjunct Professor fellowship. Al Naggari, Y. is grateful to Alexander von Humboldt (AvH) foundation for a return fellowship (Ref 3.4-1196574-EGY-GF-P).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Dedicated with great pleasure and honor to Rob Verpoorte (Leiden University, the Netherlands) and Lars Bohlin (Uppsala University, Sweden) on the occasion of their 75th birthday.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kritsky, G. The quest for the perfect hive: Ancient Mediterranean origins. In *Beekeeping in the Mediterranean from Antiquity to the Present*; Agricultural Organization “Demeter” Athens: Athens, Greece, 2017; pp. 50–56.
2. Kuropatnicki, A.K.; Kłósek, M.; Kucharzewski, M. Honey as medicine: Historical perspectives. *J. Apic. Res.* **2018**, *57*, 113–118. [[CrossRef](#)]
3. Sheppard, W.S.; Shoukry, A.K.S. The Nile honey bee—The bee of ancient Egypt in modern times. *Am. Bee J.* **2001**, *14*, 260–263.
4. Abushady, A.Z. Races of bees. In *The Hive and the Honey Bee*; Dadant & Sons: Hamilton, NY, USA, 1949; pp. 11–20.
5. Abdullah, I.; Gary, S.R.; Marla, S. Field trial of honey bee colonies bred for mechanisms of resistance against *Varroa destructor*. *Apidologie* **2007**, *38*, 67–76. [[CrossRef](#)]
6. Fasasi, K.A.; Malaka, S.L.O.; Amund, O.O. Studies on the life cycle and morphometrics of honeybees, *Apis mellifera adansonii* (Hymenoptera: Apidae) in a Mangrove area of Lagos, Nigeria. *Ife J. Sci.* **2011**, *13*, 103–109.
7. Smith, F.G. The races of honeybees in Africa. *Bee World* **1961**, *42*, 255–260. [[CrossRef](#)]
8. Simonthomas, R.T.; Simonthomas, A.M.J. *Philanthus triangulum* and its recent eruption as a predator of honeybees in an Egyptian oasis. *Bee World* **1980**, *61*, 97–107. [[CrossRef](#)]
9. Al Naggar, Y.; Codling, G.; Giesy, J.P.; Safer, A. Beekeeping and the need for pollination from an agricultural perspective in Egypt. *Bee World* **2018**, *95*, 107–112. [[CrossRef](#)]
10. Masry, S.H.D.; Ebadah, I.M.A.; Abd El-Wahab, T.E. Impact of honey bee colonies of different races on rearing *Apis mellifera lamarckii* queen larvae. *Egypt. J. plant Prot.* **2013**, *8*, 28–35.
11. Schmolz, E.; Dewitz, R.; Schricker, B.; Lamprecht, I. Energy metabolism of European (*Apis mellifera Carnica*) and Egyptian (*A. m. lamarckii*) honeybees. *J. Therm. Anal. Calorim.* **2001**, *65*, 131–140. [[CrossRef](#)]
12. Abou-Shaara, H.F.; Eid, K.S.A.; Bayoumi, S.R. Insights into the mtDNA of the Egyptian honey bees, *Apis mellifera lamarckii* using different analytical tools. *J. Entomol. Res.* **2020**, *44*, 575–580. [[CrossRef](#)]
13. Kamel, S.M.; Strange, J.P.; Sheppard, W.S. A scientific note on hygienic behavior in *Apis mellifera lamarckii* and *A. m. carnica* in Egypt. *Apidologie* **2003**, *34*, 189–190. [[CrossRef](#)]
14. El-Bermawy, S.M.; Ahmed, K.S.; Al-Gohary, H.Z.; Bayomy, A.M. Biochemical and molecular characterization for three subspecies of honey bee worker, *Apis mellifera* L. (Hymenoptera: Apidae) in Egypt. *Egypt. Acad. J. Biol. Sci. A Entomol.* **2012**, *5*, 103–115. [[CrossRef](#)]
15. El-Seedi, H.R.; Eid, N.; El-Wahed, A.A.A.; Rateb, M.E. Honey bee products: Preclinical and clinical studies of their anti-inflammatory and immunomodulatory properties. *Front. Nutr.* **2022**, *8*, 761267–761285. [[CrossRef](#)] [[PubMed](#)]
16. Yosri, N.; El-Wahed, A.A.A.; Ghonaim, R.; Khattab, O.M.; Sabry, A.; Ibrahim, M.A.A.; Moustafa, M.F.; Guo, Z.; Zou, X.; Algethami, A.F.M.; et al. Anti-viral and immunomodulatory properties of propolis: Chemical diversity, pharmacological properties, preclinical and clinical applications, and in silico potential against SARS-CoV-2. *Foods* **2021**, *10*, 1776. [[CrossRef](#)] [[PubMed](#)]
17. El-Wahed, A.A.A.; Farag, M.A.; Eraqi, W.A.; Mersal, G.A.M.; Zhao, C.; Khalifa, S.A.M.; El-Seedi, H.R. Unravelling the beehive air volatiles profile as analysed via solid-phase microextraction (SPME) and chemometrics. *J. King Saud Univ. Sci.* **2021**, *33*, 101449–101456. [[CrossRef](#)]
18. Khalifa, S.A.M.; Elashal, M.H.; Yosri, N.; Du, M.; Musharraf, S.G.; Nahar, L.; Sarker, S.D.; Guo, Z.; Cao, W.; Zou, X.; et al. Bee pollen: Current status and therapeutic potential. *Nutrients* **2021**, *13*, 1876. [[CrossRef](#)] [[PubMed](#)]
19. El-Wahed, A.A.A.; Khalifa, S.A.M.; Elashal, M.H.; Musharraf, S.G.; Saeed, A.; Khatib, A.; Tahir, H.E.; Zou, X.; Naggar, Y.A.; Mehmood, A.; et al. Cosmetic applications of bee venom. *Toxins* **2021**, *13*, 810. [[CrossRef](#)] [[PubMed](#)]
20. El-Seedi, H.R.; Khalifa, S.A.M.; El-Wahed, A.A.A.; Gao, R.; Guo, Z.; Tahir, H.E.; Zhao, C.; Du, M.; Farag, M.A.; Musharraf, S.G.; et al. Honeybee products: An updated review of neurological actions. *Trends Food Sci. Technol.* **2020**, *101*, 17–27. [[CrossRef](#)]
21. Aufschnaiter, A.; Kohler, V.; Khalifa, S.; El-Wahed, A.; Du, M.; El-Seedi, H.; Büttner, S. Apitoxin and its components against cancer, neurodegeneration and rheumatoid arthritis: Limitations and possibilities. *Toxins* **2020**, *12*, 66. [[CrossRef](#)] [[PubMed](#)]
22. Khalifa, S.A.M.; Elashal, M.; Kieliszek, M.; Ghazala, N.E.; Farag, M.A.; Saeed, A.; Xiao, J.; Zou, X.; Khatib, A.; Göransson, U.; et al. Recent insights into chemical and pharmacological studies of bee bread. *Trends Food Sci. Technol.* **2020**, *97*, 300–316. [[CrossRef](#)]
23. El-Seedi, H.R.; Ahmed, H.R.; El-Wahed, A.A.A.; Saeed, A.; Algethami, A.F.; Attia, N.F.; Guo, Z.; Musharraf, S.G.; Khatib, A. Bee stressors from an immunological perspective and strategies to improve bee health. *Vet. Sci.* **2022**, *9*, 199. [[CrossRef](#)] [[PubMed](#)]
24. Khalifa, S.A.M.; Elshafiey, E.H.; Shetaia, A.A.; El-Wahed, A.A.A.; Algethami, A.F.; Musharraf, S.G.; Alajmi, M.F.; Zhao, C.; Masry, S.H.D.; Abdel-Daim, M.M.; et al. Overview of bee pollination and its economic value for crop production. *Insects* **2021**, *12*, 688. [[CrossRef](#)] [[PubMed](#)]
25. Bunson, M. *Encyclopedia of Ancient Egypt*; Infobase Publishing: New York, NY, USA, 2014; ISBN 1438109970.
26. Kritsky, G. *The Tears of Re: Beekeeping in Ancient Egypt*; Oxford University Press: Oxford, UK, 2015; ISBN 0199361398.
27. Kritsky, G. Beekeeping from antiquity through the middle ages. *Annu. Rev. Entomol.* **2017**, *62*, 249–264. [[CrossRef](#)] [[PubMed](#)]
28. Allon, N. The Tears of Re: Beekeeping in Ancient Egypt. *J. Am. Orient. Soc.* **2019**, *139*, 775–777.
29. Hammad, M. Bees and beekeeping in ancient Egypt (a historical study) ancient Egyptian bee and its nature. *J. Assoc. Arab Univ. Tour. Hosp.* **2018**, *15*, 1–16. [[CrossRef](#)]
30. Leek, F.F. Some evidence of bees and honey in ancient Egypt. *Bee World* **1975**, *56*, 141–163. [[CrossRef](#)]
31. Gupta, R.K.; Khan, M.S.; Srivastava, R.M.; Goswami, V. History of beekeeping in developing world. In *Beekeeping for Poverty Alleviation and Livelihood Security*; Springer: Dordrecht, The Netherlands, 2014; pp. 3–62.
32. Hussein, M.H. A review of beekeeping in Arab countries. *Bee World* **2000**, *81*, 56–71. [[CrossRef](#)]

33. Amro, A.M. Pollinators and pollination effects on three canola (*Brassica napus* L.) cultivars: A case study in Upper Egypt. *J. King Saud Univ. Sci.* **2021**, *33*, 101240. [[CrossRef](#)]
34. Abou-Shaara, H.F. Expectations about the potential impacts of climate change on honey bee colonies in Egypt. *J. Apic.* **2016**, *31*, 157–164. [[CrossRef](#)]
35. Abou-Shaara, H.F.I. Morphometrical, Biological and Behavioral Studies on Some Honey Bee Races at El-Beheira Governorate. Doctoral Dissertation, Alexandria University, Alexandria, Egypt, 2009.
36. Shaibi, T.; Fuchs, S.; Moritz, R.F.A. Morphological study of honeybees (*Apis mellifera*) from Libya. *Apidologie* **2009**, *40*, 97–105. [[CrossRef](#)]
37. Rukhosh, J.R. The morphometrical study of some honeybee (*Apis mellifera* L.) (Hymenoptera: Apidae) races in Sulaimani-Iraqi Kurdistan Region. *Euphrates J. Agric. Sci.* **2021**, *13*, 23–41.
38. Zeid, A.S.A.; Schrickler, B. Antennal sensilla of the queen, half-queen and worker of the Egyptian honey bee, *Apis mellifera lamarckii*. *J. Apic. Res.* **2001**, *40*, 53–58. [[CrossRef](#)]
39. Ahmed, K.-A.; El-Bermawy, S.; El-Gohary, H.; Bayomy, A. Electron microscope study on workers antennae and sting lancets of three subspecies of honey bee *Apis mellifera* L. (Hymenoptera: Apidae) and its bearing on their phylogeny. *Egypt. Acad. J. Biol. Sci. A Entomol.* **2015**, *8*, 105–124. [[CrossRef](#)]
40. Al-Kahtani, S.N.; Taha, E.K.A. Morphometric study of Yemeni (*Apis mellifera jemenitica*) and Carniolan (*A. m. carnica*) honeybee workers in Saudi Arabia. *PLoS ONE* **2021**, *16*, e0247262. [[CrossRef](#)]
41. Meixner, M.D.; Leta, M.A.; Koeniger, N.; Fuchs, S. The honey bees of Ethiopia represent a new subspecies of *Apis mellifera*—*Apis mellifera simensis* n. ssp. *Apidologie* **2011**, *42*, 425–437. [[CrossRef](#)]
42. Bucu, S.M.; Collins, A.M.; Rinderer, T.E.; Lancaster, V.A.; Sylvester, H.A.; Crewe, R.M.; Davis, G.L. Morphometric differences between south American Africanized and South African Scutellata) honey bees. *Apidologie* **1987**, *18*, 217–222. [[CrossRef](#)]
43. Alabdali, E.A.; Ghramh, H.A.; Ibrahim, E.H.; Ahmad, Z.; Asiri, A.N. Characterization of the native honey bee (*Apis mellifera jemenitica*) in the south western region of Saudi Arabia using morphometric and genetic (mtDNA COI) characteristics. *Saudi J. Biol. Sci.* **2021**, *28*, 2278–2284. [[CrossRef](#)]
44. Alqarni, A.S.; Hannan, M.A.; Owayss, A.A.; Engel, M.S. The indigenous honey bees of Saudi Arabia (Hymenoptera, Apidae, *Apis mellifera jemenitica* Ruttner): Their natural history and role in beekeeping. *Zookeys* **2011**, *134*, 83–98.
45. Elfeel, M.A.M. *Studies on the Egyptian Honeybee Race Apis mellifera lamarckii Cockerel in Siwa Oasis as a New Isolated Region*; Cairo University: Cairo, Egypt, 2008.
46. Alburaki, A. Morphometrical study on Syrian honeybee (*Apis mellifera syriaca*) introduction important social insects known in the honeybee evolutionary lineages (Ruttner, 1978). Biometrical studies were also done on other honeybee species Abd. *Emir. J. Food Agric.* **2008**, *20*, 89–93. [[CrossRef](#)]
47. Abdelkader, F. Situation of beekeeping in North Africa. *J. Apitherapy Nat.* **2020**, *3*, 1–9. [[CrossRef](#)]
48. Zeid, A.S.A. Comparison of eggs produced by queens, halfqueens and worker bees and weight of emerging workers in *Apis mellifera lamarckii*. *J. Apic. Res.* **2020**, *59*, 685–690. [[CrossRef](#)]
49. Abdel-Rahman, M.F. Chalkbrood tolerance in *Apis mellifera lamarckii* and *A. m. carnica* in Egypt. *J. Agric. Sci. Assiut Univ.* **2009**, *40*, 125–132.
50. Abou-Shaara, H.F.; Abbas, A.S.; Al-Kahtani, S.N.; Taha, E.-K.A.; Khan, K.A.; Jamal, Z.A.; Alotaibi, M.A.; Ahmad, B.; Khan, N.A.; Qamer, S. Exploring the non-coding regions in the mtDNA of some honey bee species and subspecies. *Saudi J. Biol. Sci.* **2021**, *28*, 204–209. [[CrossRef](#)]
51. El-Niweiri, M.A.A.; Moritz, R.F.A. Mitochondrial discrimination of honeybees (*Apis mellifera*) of Sudan. *Apidologie* **2008**, *39*, 566–573. [[CrossRef](#)]
52. Abou-Shaara, H.F.; Al-Ghamdi, A.A.; Khan, K.A.; Al-Kahtani, S.N. Genetic network analysis between *Apis mellifera* subspecies based on mtDNA argues the purity of specimens from North Africa, the Levant and Saudi Arabia. *Saudi J. Biol. Sci.* **2021**, *28*, 2718–2725. [[CrossRef](#)]
53. Nielsen, D.I.; Ebert, P.R.; Page, R.E.; Hunt, G.J.; Guzmán-Novoa, E. Improved polymerase chain reaction-based mitochondrial genotype assay for identification of the Africanized honey bee (Hymenoptera: Apidae). *Ann. Entomol. Soc. Am.* **2000**, *93*, 1–6. [[CrossRef](#)]
54. Kandemir, I.; Pinto, M.A.; Meixner, M.D.; Sheppard, W.S. Hinf-I digestion of cytochrome oxidase I region is not a diagnostic test for *A. m. lamarckii*. *Genet. Mol. Biol.* **2006**, *749*, 747–749. [[CrossRef](#)]
55. Eimanifar, A.; Kimball, R.T.; Braun, E.L.; Moustafa, D.M.; Haddad, N.; Fuchs, S.; Grünewald, B.; Ellis, J.D. The complete mitochondrial genome of the Egyptian honey bee, *Apis mellifera lamarckii* (Insecta: Hymenoptera: Apidae). *Mitochondrial DNA Part B* **2017**, *2*, 270–272. [[CrossRef](#)] [[PubMed](#)]
56. El-Barbary, N.S.; Youssef, M.K. Biochemical genetic studies in honeybees *Apis mellifera* L. *J. Plant Prot. Pathol.* **2006**, *31*, 1107–1121. [[CrossRef](#)]
57. Abou-shaara, H.F. Utilizing bioinformatics to detect genetic similarities between African honey bee subspecies. *J. Genet.* **2019**, *98*, 96–102. [[CrossRef](#)]
58. Pernal, S.F.; Sewalem, A.; Melathopoulos, A.P. Breeding for hygienic behaviour in honeybees (*Apis mellifera*) using free-mated nucleus colonies. *Apidologie* **2012**, *43*, 403–416. [[CrossRef](#)]

59. Alacioa, M.A.P.; Iginib, E.E.F.; Uffinengoa, S.R.R.; Odriguez, E.M.R.; Oyob, M.L.D.E.L.H.; Edascarrasbureb, E.L.B. Changes in a population of *Apis mellifera* L. selected for hygienic behaviour and its relation to brood disease tolerance. *Apidologie* **2000**, *31*, 471–478.
60. Khan, K.A.; Ghramh, H.A. An investigation of the efficacy of hygienic behavior of various honey bee (*Apis mellifera*) races toward *Varroa destructor* (Acari: Varroidae) mite infestation. *J. King Saud Univ. Sci.* **2021**, *33*, 101393. [[CrossRef](#)]
61. Boecking, O.; Spivak, M. Behavioral defenses of honey bees against *Varroa jacobsoni* Oud. *Apidologie* **1999**, *30*, 141–158. [[CrossRef](#)]
62. Parker, R.; Guarna, M.M.; Melathopoulos, A.P.; Moon, K.-M.; White, R.; Huxter, E.; Pernal, S.F.; Foster, L.J. Correlation of proteome-wide changes with social immunity behaviors provides insight into resistance to the parasitic mite, *Varroa destructor*, in the honey bee (*Apis mellifera*). *Genome Biol.* **2012**, *13*, R81. [[CrossRef](#)] [[PubMed](#)]
63. Spivak, M.; Gilliam, M. Hygienic behaviour of honey bees and its application for control of brood diseases and Varroa: Part II. Studies on hygienic behaviour since the Rothenbuhler era. *Bee World* **1998**, *79*, 169–186. [[CrossRef](#)]
64. Pivak, M.S.; Euter, G.S.R. Resistance to American foulbrood disease by honey bee colonies *Apis mellifera* bred for hygienic behavior. *Apiacta* **2001**, *32*, 555–565.
65. Spivak, M.; Danka, R.G. Perspectives on hygienic behavior in *Apis mellifera* and other social insects. *Apidologie* **2021**, *52*, 1–16. [[CrossRef](#)]
66. Hamiduzzaman, M.; Emsen, B.; Hunt, G.J.; Subramanyam, S.; Williams, C.E.; Tsuruda, J.M.; Novoa, E.G. Differential gene expression associated with honey bee grooming behavior in response to Varroa mites. *Behav. Genet.* **2017**, *47*, 335–344. [[CrossRef](#)] [[PubMed](#)]
67. Zaitoun, S.T.; Al-Ghzawi, A.M.; Shannag, H.K. Grooming behaviour of *Apis mellifera syriaca* towards *Varroa jacobsoni* in Jordan. *J. Appl. Entomol.* **2001**, *125*, 85–87. [[CrossRef](#)]
68. Balhareth, H.M.; Alqarni, A.S.; Owayss, A.A. Comparison of hygienic and grooming behaviors of indigenous and exotic honeybee (*Apis mellifera*) races in central Saudi Arabia. *Int. J. Agric. Biol.* **2012**, *14*, 1005–1008.
69. Russo, R.M.; Liendo, M.C.; Landi, L.; Pietronave, H.; Merke, J.; Fain, H.; Muntaabski, I.; Palacio, M.A.; Rodríguez, G.A.; Lanzavecchia, S.B.; et al. Grooming behavior in naturally varroa-resistant *Apis mellifera* colonies from North-central Argentina. *Front. Ecol. Evol.* **2020**, *8*, 590281–590293. [[CrossRef](#)]
70. Allam, S.; Zakaria, M. Stimulation effects of the essential oils on the sensory and defensive behaviors of Egyptian honey bees towards Varroa invasion. *Acarines J. Egypt. Soc. Acarol.* **2009**, *3*, 29–36. [[CrossRef](#)]
71. Wehbe, R.; Frangieh, J.; Rima, M.; El Obeid, D.; Sabatier, J.M.; Fajloun, Z. Bee venom: Overview of main compounds and bioactivities for therapeutic interests. *Molecules* **2019**, *24*, 2997. [[CrossRef](#)] [[PubMed](#)]
72. M Mansour, A.; Elfiky, A.A.; Fahmy, A.; Diab, A.A. Therapeutic effect of bee venom formulation in the treatment of FMD viral infection: Preclinical and clinical evaluation. *Int. J. Sci. Res. Publ.* **2016**, *6*, 711–728.
73. Abu-Zeid, E.H.; Khalifa, B.A.; Elewa, Y.H.A.; Arisha, A.H.; Ismail, T.A.; Hendam, B.M.; El Abdel-Hamid, S. Bee venom *Apis mellifera lamarckii* rescues blood brain barrier damage and neurobehavioral changes induced by methyl mercury via regulating tight junction proteins expression in rat cerebellum. *Food Chem. Toxicol.* **2021**, *154*, 112309. [[CrossRef](#)] [[PubMed](#)]
74. Singh, R.K.; Sharma, G.K.; Mahajan, S.; Dhama, K.; Basagoudanavar, S.H.; Hosamani, M.; Sreenivasa, B.P.; Chaicumpa, W.; Gupta, V.K.; Sanyal, A. Foot-and-mouth disease virus: Immunobiology advances in vaccines and vaccination strategies addressing vaccine failures—An Indian perspective. *Vaccines* **2019**, *7*, 90. [[CrossRef](#)]
75. Zalat, S.; Abouzeid, A.; Ibrahim, A.; Abd El-Aal, A. Protein pattern of the honeybee venoms of Egypt. *Egypt. J. Biol.* **2002**, *4*, 42–46.
76. El-Wahed, A.A.A.; Khalifa, S.A.; Sheikh, B.Y.; Farag, M.A.; Saeed, A.; Larik, F.A.; Koca-Caliskan, U.; AlAjmi, M.F.; Hassan, M.; Wahabi, H.A.; et al. Bee venom composition: From chemistry to biological activity. In *Studies in Natural Products Chemistry*; Elsevier: Amsterdam, The Netherlands, 2018; Volume 60, pp. 459–484. ISBN 9780444641816.
77. García, M.L.G.; Plischuk, S.; Bravi, C.M.; Reynaldi, F.J. An overview on honeybee colony losses in Buenos Aires province, Argentina. *Sociobiology* **2019**, *66*, 75–80. [[CrossRef](#)]
78. Kim, Y.-W.; Chaturvedi, P.; Chun, S.; Lee, Y.; Ahn, W. Honeybee venom possesses anticancer and antiviral effects by differential inhibition of HPV E6 and E7 expression on cervical cancer cell line. *Oncol. Rep.* **2015**, *33*, 1675–1682. [[CrossRef](#)]
79. Abdel-Monsef, M.M.; Zidan, H.A.; Darwish, D.A.; Masoud, H.M.; Helmy, M.S.; Ibrahim, M.A. Biochemical isolation and characterization of hyaluronidase enzyme from venom of Egyptian honey bee *Apis mellifera lamarckii*. *J. Apic. Sci.* **2020**, *64*, 153–164. [[CrossRef](#)]
80. Putz, T.; Ramoner, R.; Gander, H.; Rahm, A.; Bartsch, G.; Bernardo, K.; Ramsay, S.; Thurnher, M. Bee venom secretory phospholipase A2 and phosphatidylinositol-homologues cooperatively disrupt membrane integrity, abrogate signal transduction and inhibit proliferation of renal cancer cells. *Cancer Immunol. Immunother.* **2007**, *56*, 627–640. [[CrossRef](#)] [[PubMed](#)]
81. Kang, G.H.; Lee, S.; Choi, D.B.; Shin, D.; Kim, J.; Yang, H.; Bae, H. Bee venom phospholipase A2 ameliorates atherosclerosis by modulating regulatory T cells. *Toxins* **2020**, *12*, 609. [[CrossRef](#)] [[PubMed](#)]
82. Kim, H.; Keum, D.J.; Kwak, J.W.; Chung, H.S.; Bae, H. Bee venom phospholipase A2 protects against acetaminophen-induced acute liver injury by modulating regulatory T cells and IL-10 in mice. *PLoS ONE* **2014**, *9*, e114726. [[CrossRef](#)] [[PubMed](#)]
83. Darwish, D.A.; Masoud, H.M.M.; Abdel-Monsef, M.M.; Helmy, M.S.; Zidan, H.A.; Ibrahim, M.A. Phospholipase A2 enzyme from the venom of Egyptian honey bee *Apis mellifera lamarckii* with anti-platelet aggregation and anti-coagulation activities. *J. Genet. Eng. Biotechnol.* **2021**, *19*, 10. [[CrossRef](#)] [[PubMed](#)]
84. Patel, A. Effect of honeybee venom (*Apis mellifera*) on respiratory functions of hypercholesterolemic male albino rats. *Assiut Vet. Med. J.* **2019**, *67*, 9–25.