Journal of Plant Protection and Pathology

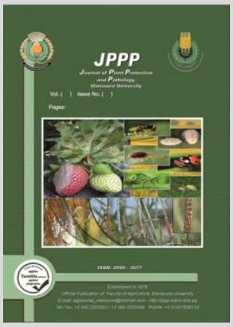
Journal homepage: www.jppp.mans.edu.eg
Available online at: www.jppp.journals.ekb.eg

Species Distribution Modeling of Potential Invasion of Dwarf Honey Bee, *Apis florea* Fab., to Africa and Europe after Occurrence in Egypt in View of Climatic Changes

Cross Mark

Abou-Shaara, H. F.[1]; H. M. Mahfouz[2*] and A. A. Owayss[3]

[1] Dept. of Plant Prot., Fac. of Agric., Damanhour Univ., Damanhour, 22516, Egypt
[2] Dept. of Plant Prot., Fac. of Environ. Agric. Sci., Arish Univ., 45511, Egypt
[3] Dept. of Plant Prot., Fac. of Agric., Fayoum Univ., 63514, Egypt



ABSTRACT

Recently, the dwarf honey bee (DB), *Apis florea* Fab, has invaded certain eastern parts of Egypt. DB is expected to invade other national localities and extends to international regions. The current study shades light on the ability of DB to spread through Egypt towards certain regions in Africa and southern Europe. Maxent, as a species distribution modeling software analysis, was applied combining with environmental variables of current and future circumstances, i.e. during 2050 up to 2070. The obtained maps predict the limited spread of DB via southern Europe, under current conditions, while supports the potential spread of DB across northern and western parts of Egypt within next few years. The futuristic maps emphasized the possible spread of DB towards southern Europe especially Spain and Portugal, while the wide invasion of DH in other European countries is not expected. Limited ability of DB to spread all over Africa is predictable, while, northern African regions are preferred. Possible consequences of the spread of DB into other regions are discussed.

Keywords: *Apis florea*, modeling, global distribution, climate change.

INTRODUCTION

The honey bees, *Apis* spp., contribute greatly in the agricultural production worldwide especially the managed honey bee, *Apis mellifera* (Southwick and Southwick, 1992; Morse and Calderone, 2000; Breeze et al., 2011). Honey bee species are distributed geographically, considering *A. mellifera* as a worldwide species, while other species including the dwarf honey bee (DB), *A. florea* is mainly located in Asia (Ruttner, 1988; Rinderer et al., 1995; Otis, 1996; Hepburn and Radloff, 2011; Ilyasov et al., 2020). DB succeeded to invade various regions in Asia including the Arabian Peninsula (Al-Kahtani and Taha, 2014; Taha et al., 2016). Recently, DB has an extended range to be found in eastern Egypt (Shebl, 2017).

DH nests one comb-colony exposed to open air unlike cavity-nesting bees (Rinderer et al., 1996). The body size of DB is small compared to other *Apis* species (Rinderer et al., 1995; Hepburn and Radloff, 2011). Furthermore, a population of a DH colony is lower than that of a typically *A. mellifera*. Although productivity is lower than that of *A. mellifera*, a commercial honey of DB is traditionally produced in some countries (Dutton and Simpson, 1977; Dutton and Free, 1979). DB contributes in plant pollination (Taha et al., 2016). Actually, few studies are available on the competition between DB and other bee pollinators. Invasion of DB to new environments can alter balance and can spread diseases among native pollinators. Unfortunately, certain diseases of *A. mellifera* have been detected in DB (Zhang et al., 2012).

The recent occurrence of DB to Egypt is a probable gate to a wide invasion to northern Africa and nearby European regions. Such biological invasion can misbalance the complex relationship between pollinators and plants. Therefore, predicting the potential expansion of DB in Africa and Europe is very important for early planning management particularly under futuristic climatic changes. Previous studies have highlighted the potential effects of climate change including temperature on pollinators, beekeeping, and bee diseases (Le Conte and Navajas, 2008; Hegland et al., 2009; Rader et al., 2013; Yoruk and Sahinler, 2013; Abou-Shaara, 2016; Jamal et al., 2021).

Climatic fluctuations, especially temperature changes can affect the prevalence of certain organisms (Jamal et al., 2021). Prediction of futuristic climates depends mainly on environmental variables (Hosni et al., 2020; Silva et al., 2020; Jamal et al., 2021) specifically those depend on Worldclim database (Hijmans et al. 2005) combined with modeling programs (Phillips et al. 2006; Phillips and Dudík 2008; Jamal et al., 2021). Many modeling software programs are utilized during analysis (Silva et al., 2020), e.g. MaxEnt (Hosni et al., 2020; Jamal et al., 2021). The current study aims to analyze the potential distribution of DB in Africa and Europe based on DB invasion to eastern Egypt. Probable consequences to the environment are also discussed.

MATERIALS AND METHODS

1. Data of DB in Egypt

Locations invaded by DB in Egypt were basically confirmed from data of Global Biological Information

*** Corresponding author.**
E-mail address: hmahfouz@Aru.edu.eg
DOI: 10.21608/jppp.2021.206735

Facility (GBIF.org, October 2020: https://doi.org/ 10.15468/dl.s8ucvb). These data concentrate areas near to the eastern parts of Egypt especially Ismailia Governorate (Fig. 1). Unluckily, the available data about the occurrence of DB in Egypt are rare, i.e. such bee species was recorded in Egypt within the last few years (Shebl, 2017) more repetition of the data was detected, and 19 locations were used in the analysis

Fig. 1. A Google Erath map shows locations of *Apis florea* in Egypt.
(White arrow indicates the spread direction of this bee species).

2. Variable selection

Firstly, the 19 variables in worldclim.org (WorldClim v2.1, January 2020) with a spatial resolution of about 5 km^2 were screened, then the variables with known spatial problems and discontinuous spatial anomalies were not considered (Escobar et al., 2014; Samy et al., 2016; Alkishe et al., 2017; Jamal et al., 2021). Since temperature is more substantial for honey bees compared to relative humidity (Abou-Shaara, 2014; Abou-Shaara et al., 2017) six variables derived from temperature datasets were included in the present study. These variables are important to understand species distribution under climate change conditions (Jamal et al., 2021). The six variables represent (1) annual mean temperature or bio1, (2) mean diurnal range or bio2, (3) maximum temperature of warmest month or bio5, (4) minimum temperature of coldest month or bio6, (5) mean temperature of warmest quarter or bio10, and (6) mean temperature of coldest quarter or bio11.

3. Distribution of DB in Egypt and nearby countries

The analysis uses maximum entropy modeling of Maxent v 3.4.1 (Phillips et al., 2020) was applied according to software guidelines. Analysis outputs were presented as a map showing potential distribution of DB in the study area. The color legends of the map were typically generated by the cumulative outputs of the model. Specific titles for suitability (from very high to very low) were used instead of numbers from 0 to 100.

4. Futuristic potential distribution of DB

The anticipative potential spread of DB in Egypt and nearby areas including African and southern European regions was predicted utilizing futuristic datasets of the Meteorological Research Institute (MRI-ESM2-0) in the Coupled Model Intercomparison Project Phase 6 (CMIP6) (Eyring et al., 2016). The aforementioned variables were used to model futuristic conditions using Maxent v 3.4.1 (Phillips et al., 2020). Typically two-time points in the future: 2050 and 2070 decades representing average from 2041 to 2060 and from 2061 to 2080, respectively were downloaded. Each time point has two limits of predictions (i.e. two Shared Socio-economic Pathways or SSPs: 126 and 585). Variables of current conditions were firstly projected with variables of future conditions (SSP 126 and SSP 585) then variables of SSP 126 were projected with those of SSP 585 to obtain a combined map for future conditions representing the average of the two SSPs. The presentation of all maps can accurately help to understand the potential distribution of DB in the study areas. In addition, the distribution of DB in Egypt was mainly highlighted. All maps were reclassified using ArcGIS 10.5 to emphasize the suitability for DB according to Jamal et al. (2021).

5. Performance evaluation

Specific parameters were selected during the run of the model to evaluate its performance according to the Maxent guidelines (Phillips, 2017). Each of jackknife tests, omission rates, and the area under curve (AUC) for testing data were used. Furthermore, the percentages of contribution of the used variables in the model were presented.

RESULTS AND DISCUSSION

Results

1. DB distribution

The probable spread of DB from Egypt to the west, i.e. to invade Libya, Tunisia, Algeria, and certain parts of Morocco can significantly occur (Fig. 2). The expected spread of DB from eastern Egypt towards the south, through the mountainous region of the Red Sea, can greatly take place including some coastal parts of Sudan. However, possible invasion of other African countries is not supported by the applied model map. Under current environmental conditions, probable spread of DB towards Europe, through the contact zone between Morocco and Spain, is very limited (Fig. 2). Additionally, this map shows the potential occurrence of this bee species in Jordan and the Levant.

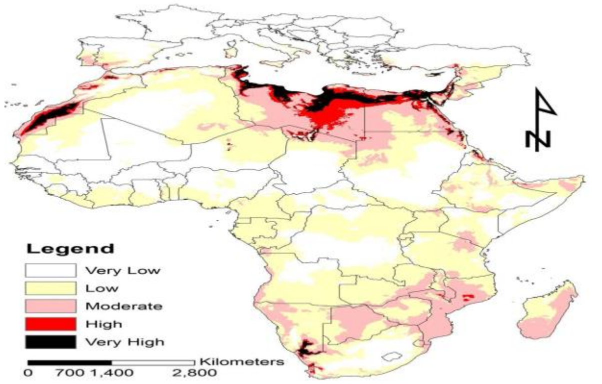


Fig. 2. Potential spread of *Apis florea* out of eastern Egypt to Africa and southern Europe.

2. Futuristic distribution of DB (2050 decade)

The anticipative spread of DB through northern and western Egypt is highly expected during 2050 (SSP 126 and SSP 585). The maps also support the spread from Egypt towards Morocco, and potentially from Morocco towards Spain and Portugal. The high legend of SSP 585 predicts limited spread in some areas in Egypt and Libya compared to those of SSP 126 (Fig. 3). The maps not supporting the DB potential spread out of Egypt to other African countries. The map based on the projection of SSP 126 with SSP 585 (Fig. 4) which expects the spread of DB out of Egypt towards the west with a prediction to invade Europe through Spain, and towards the south to invade some parts in Sudan.

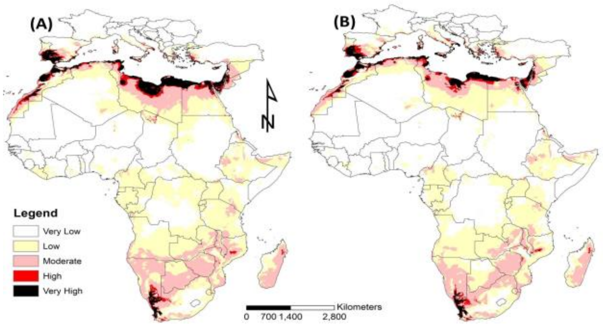


Fig. 3. Potential spread of *Apis florea* out of eastern Egypt to Africa and southern Europe during 2050. (A= SSP 126 and B= SSP 585).

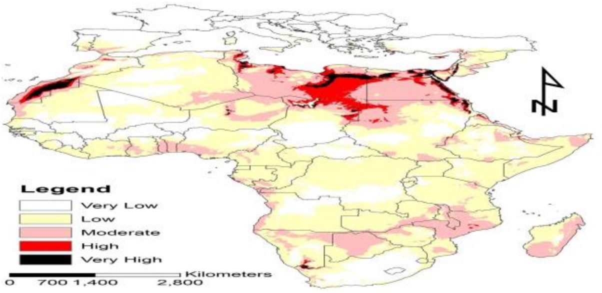


Fig. 4. Potential spread of *Apis florea* out of eastern Egypt to Africa and southern Europe during 2050. (Map is the projection of SSP 126 with SSP 585).

3. Futuristic distribution of DB (2070 decade)

The prospected situation during 2070, based on the maps of SSP 126 and SSP 585, is greatly similar to the expectation based on that of 2050 (Fig. 5). This declares the limited ability of DB to invade more regions during 2070 than 2050. In these maps, the spread of DB through northern parts of Egypt is more expected than southern ones. In addition, the spread towards Europe especially out of Morocco to Spain is expected. DB invasion out of Egypt to Sub-Saharan and specific regions in South Africa shows high and very high suitability for this bee species. A map based on the projection of SSP 126 with SSP 585 (Fig. 6) indicates the concentration of DB in coastal regions of Africa towards some parts in Europe especially Spain. This map does not support the spread of DB towards Sudan and other African countries.

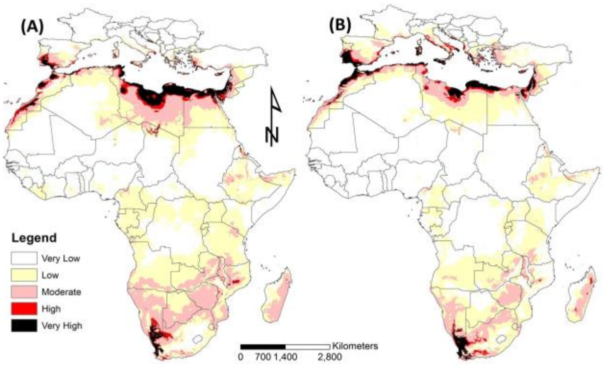


Fig. 5. Potential spread of *Apis florea* out of eastern Egypt to Africa and southern Europe during 2070. (A= SSP 126 and B= SSP 585).

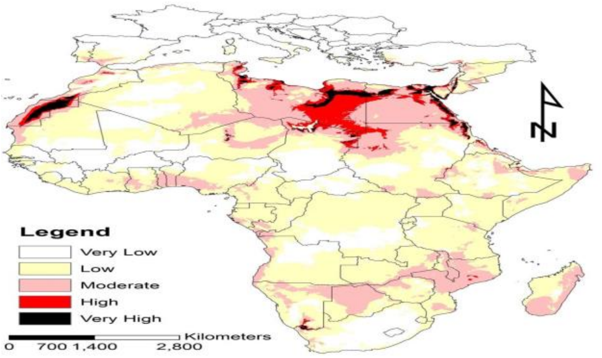


Fig. 6. Potential spread of *Apis florea* out of eastern Egypt to Africa and southern Europe during 2070. (Map is the projection of SSP 126 with SSP 585).

On the other hand, map (Fig. 7) suggests the potential changes in distribution of DB in Egypt under current conditions and in future, i.e. in 2050 until 2070. It is clear that this bee species can exist in many areas, spectacularly in northern parts and certain coastal parts of the Red Sea. Distribution map expected in 2070 proposes some limitations in the spread of this bee species towards southern parts of Egypt compared to that of current conditions or of expected map of 2050.

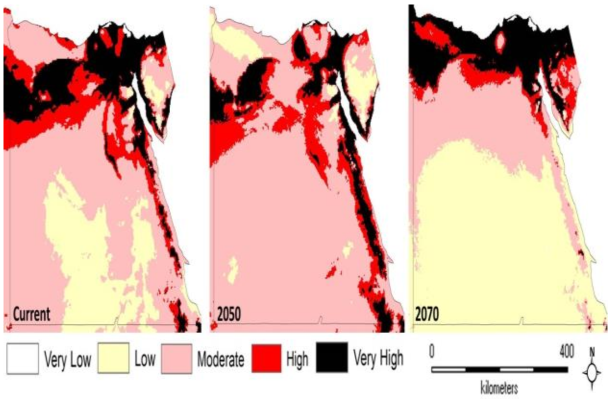


Fig. 7. Potential spread of *Apis florea* in Egypt under current conditions and that expected during 2050 or 2070 decades.

4. Model performance

The tested six variables contributed in the model by 39.0%, 29.2%, 16.8%, 5.9%, 5.6%, and 3.4% for bio 11, bio 10, bio 6, bio 2, bio 1, and bio 5, respectively. Therefore, mean temperature of the coldest quarter, mean temperature of the warmest quarter, and minimum temperature of the coldest month represented almost contribution, while the other variables contributed only 14.9% of the total. Highly suitable ranges of these variables for DB are shown in Fig. 8. These ranges were 21-24°C, 11-13°C, 34-36°C, 7-9°C, 27-29°C, and 14-15°C for bio 1, bio 2, bio 5, bio 6, bio10, and bio11, respectively. Thus, the perfect range across all variables was from 7 to 36°C.

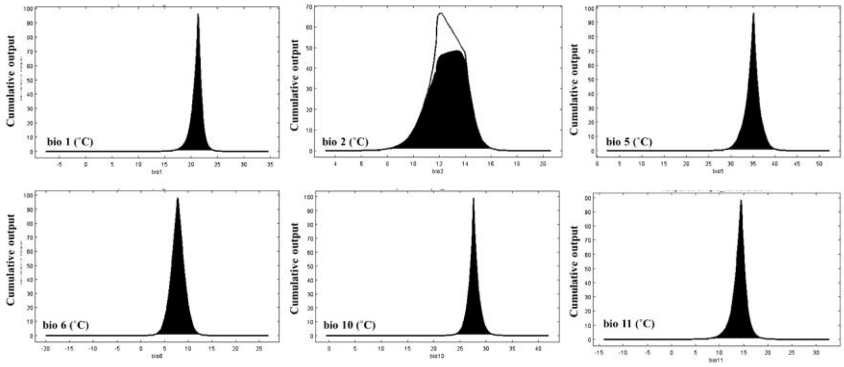


Fig. 8. Response curves of tested variables ordered by their contribution in the model: annual mean temperature (bio1), mean diurnal range (bio2), max temperature of the warmest month (bio5), min temperature of the coldest month (bio6), mean temperature of the warmest quarter (bio10), and mean temperature of the coldest quarter (bio11).

The omission rate of test data in this study is close to the predicted omission at fractional value more than 0.6 (Fig. 9A). Area under the curvy (AUC) for the test data was very high (0.999±0.001) as shown in the receiver operating characteristic curve (ROC) (Fig. 9B). These figures indicate good performance of the utilized model in the analysis considering the available data.

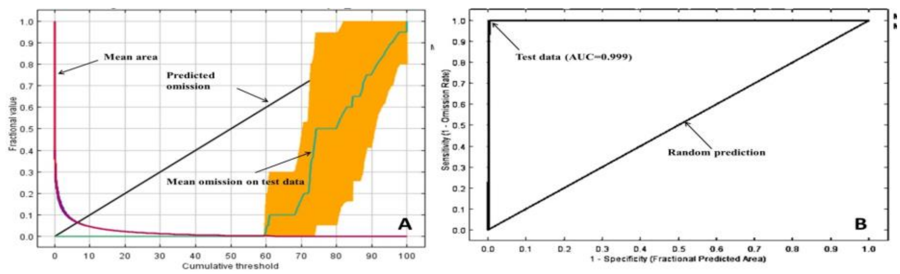


Fig. 9. Omission rate for test data (A) and curve of receiver operating characteristic for the test data (B).

The regularized gain value was more than 1 for all the tested variables except bio 2 and bio 5. The highest gain was to bio 11, followed by bio 1, bio 10, bio 6, bio5, and bio 2, respectively. Consequently, bio 11 has the most useful information when applied in isolation compared to other tested variables. Moreover, all variables have high values of AUC (more than 0.92) except bio 2 (between 0.76 to 0.78) (Fig. 10).

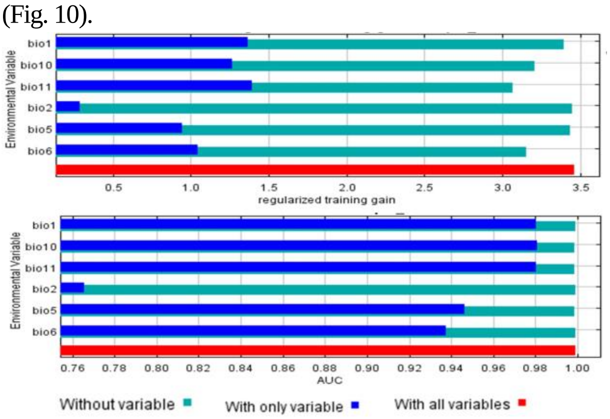


Fig. 10. Jackknife test of variable importance (regularized training gain) and area under curvy (AUC) for the tested variables in the analysis.

Discussion

1. Current distribution of DB

The generated map, based on the environmental variables of current conditions, declares limited ability for this bee species to invade Europe. On the other hand, transition towards southern Egypt then to certain parts of Sudan is suggested, especially in areas alongside the Red Sea. These two expectations are highly supported by status of this bee species in the study area as no DB was reported in Europe or in the Sub-Saharan region until now. Actually, invasion risk areas mainly locate west of Egypt (Libya to Morocco). Accordingly, a model study displays high suitability of the area extended out of Egypt to Morocco for this bee species (Silva et al., 2020). This expectation is advocated by the ability of DB to adapt with desert conditions, as DB exists in the Arabian Peninsula (Dutton and Free, 1979; Al-Kahtani and Taha, 2014; Taha et al., 2016) where arid and warm conditions dominate almost the year (Abou-Shaara et al., 2013). In addition, DB occurred in Jordan (Haddad et al., 2009). This occurrence was notified in the aforementioned maps.

2. Futuristic distribution (2050)

A predictable map for 2050 shows a potential invasion of Europe by DB out of Morocco. Probably, this bee species can colonize southern Europe within the next few years. This expectation is very logic as the spread of DB from Egypt towards the west to inhabit various countries in northern Africa is strongly endured by maps of current and futuristic (2050) conditions. Close distance between Morocco and southern parts of Spain or Portugal represents a gate for invasion of this bee species towards Europe in the near future. All studied maps not supporting the spread of DB from Egypt to central or southern parts of Arica. Formerly, DB was recorded in Sudan and Ethiopia (Mogga and Ruttner, 1988; Bezabih et al., 2014). Meanwhile, those maps not showing any DB colonization towards the south to inhabit other African countries. This may be due to the unsuitable environmental conditions at the Equator for this bee species. Therefore, DB is not proposed to invade other African countries out of the southern border of Egypt.

3. Futuristic distribution (2070)

Insignificant changes in ability of DB to invade Europe or some parts of Africa were predicted in 2070 compared to 2050. This reflects that changes in variables utilized in this model are not quite enough to cause major changes in the invasive ability of DB to enter new regions. All maps of the conducted model declare a wide spread range and establishment of DB in northern parts of Africa, with some expectation to invade Europe through Morocco-Spain gate. These maps display an ability of this bee species to adapt with desert conditions in northern Africa as well. Invasions towards central or southern parts of Africa are not expected. This hypothesis depends on the status of natural honey bees enemies, e.g. birds, ants, annimals etc..., as DB builds separate colonies, each in one comb exposed to open air. Therefore, successful colonization of this bee species in such regions is not greatly expected. Concerning Europe, it is worth noting to mention that colonization of DB in Europe will need a long time to take place.

The present study supposes that by the time DB could be a common exotic bee species in different regions of Egypt particularly northern and central parts. Thus, dietary competition with other pollinators, e.g. indigenous honey bee or wild bee species is expected. Although competition is another problem, migratory behavior and potentiality of DB to transmit known or new diseases to domesticated or wild bee species are significant obstacles, coinciding with decline in bee population. These possible consequences should be widely investigated in those areas invaded by DB. Factually, DB is infected by numerous diseases (Abrol, 2020) including viruses that infect A. mellifera (Zhang et al., 2012). Regarding bee pests and their natural enemies (Abou-Shaara and Staron, 2019) it is prospected that over-load widespread transmission of bee pests relevant to DB may lead to misbalanced relationship with their biocontrol agents. Such relationship requires further investigations.

4. Model performance

Mean temperature of the coldest quarter, mean temperature of the warmest quarter, and min temperature of the coldest quarter showed almost contribution in the tested model. All variables supported the suitability of temperature range (7°C to 36°C) for DB. Such range is very suitable for foraging activity of honey bees (Abou-Shaara, 2014; Abou-Shaara et al., 2017). Accordingly, the present model-generated maps display significant reliability for potential distribution of DB. High performance of the utilized model may due to high value of AUC (0.999±0.001) for the test data. Accordingly, AUC value (over 0.75) is an indicator to a very good fit of the model (Mulieri and Patitucci, 2019; Jamal et al., 2021). In addition, the jackknife tests for test data showed high AUC value (over 0.75) for all the inspected environmental variables.

CONCLUSION

The current study analyzed the potential spread of the Dwarf honey bee (DB), Apis florea, out of Egypt towards northern parts of Africa then to Europe, and towards south Egypt to invade other African countries. Furthermore, spread of DB in Egypt in response to climate conditions was investigated. The study analyzed current and potential futuristic distribution of DB during 2050 and 2070 decades utilizing a specific climate model that exhibited significant performance. Potential spread of DB in northern Africa and its possible invasion to southern parts of Spain and Portugal through Morocco was also highlighted. This expectation is supported only by futuristic maps and not by those of the current conditions. Invasion of DB towards other African countries thorough south Egypt is not supported by this study. Climatic conditions can shape the futuristic spread of this bee species in the studied area starting from Egypt. Spread of DB in Egypt during the near future is expected especially in the northern parts. Continual screening of DB in countries at risk should be investigated. Predictive potential consequences on the wild pollinators and domestic bees should be worthy noted.

REFERENCES

Abou-Shaara HF (2014) The foraging behaviour of honey bees, *Apis mellifera*: a review. Vet Med 59(1):1-10.

Abou-Shaara HF (2016) Expectations about the potential impacts of climate change on honey bee colonies in Egypt. J Apic 31 (2): 157-164.

Abou-Shaara HF, Al-Ghamdi AA, Mohamed AA (2013) Honey bee colonies performance enhance by newly modified beehives. J Apic Sci 57(2), 45-57.

Abou-Shaara HF, Owayss AA, Ibrahim YY, Basuny NK (2017) A review of impacts of temperature and relative humidity on various activities of honey bees. Insect Soc 64, 455-463. https://doi.org/ 10.1007/ s00040-017-0573-8

Abou-Shaara HF, Staron M (2019) Present and future perspectives of using biological control agents against pests of honey bees. Egy J Biol Pest Con 29:24. https://doi.org/10.1186/s41938-019-0126-8

Abrol DP (2020) Diseases and enemies of dwarf honeybees *Apis florea* and *Apis andreniformis*. The Future Role of Dwarf Honey Bees in Natural and Agricultural Systems, 77-94.

Al-Kahtani SN, Taha EKA (2014) Morphometric studies on dwarf honey bee Apis florea F. workers in Saudi Arabia. J Apic Sci 58(1), 127-134.

Alkishe AA, Peterson AT, Samy AM (2017) Climate change influences on the potential geographic distribution of the disease vector tick Ixodes ricinus. PLoS ONE 12(12): e0189092. https://doi.org/ 10.1371/ journal. pone.0189092

Bezabih G, Adgaba N, Hepburn HR, Pirk CWW (2014) The territorial invasion of *Apis florea* in Africa. Afr Entomol 22(4), 888-890.

Breeze TD, Bailey AP, Balcombe KG, Potts SG (2011) Pollination services in the UK: How important are honeybees?. Agri Eco Env 142(3-4): 137-143

Dutton R, Simpson J (1977) Producing honey with Apis florea in Oman. Bee world, 58(2), 71-76.

Dutton RW, Free JB (1979) The present status of beekeeping in Oman. Bee World, 60(4), 176-185.

Escobar LE, Lira-Noriega A, Medina-Vogel G, Townsend PA (2014) Potential for spread of the white-nose fungus (*Pseudogymnoascus destructans*) in the Americas: use of Maxent and Niche A to assure strict model transference. Geospat Health 9(1): 221–229.

Eyring V, Bony S, Meehl GA, Senior CA, Stevens B, Stouffer RJ, Taylor KE (2016) Overview of the coupled model intercomparison project phase 6 (CMIP6) experimental design and organization, Geoscientific Model Development 9: 1937-1958. doi:10.5194/gmd-9-1937-2016, 2016.

Haddad N, Fuchs S, Hepburn HR, Radloff SE (2009) *Apis florea* in Jordan: source of the founder population. Apidologie 40(4), 508-512.

Hegland SJ, Nielsen A, Lazaro A, Bjerknes AL, Totland O (2009) How does climate warming affect plant-pollinator interactions?. Ecol lett 12: 184-195. https://doi.org/ 10.1111/j.1461-0248.2008.01269.x

Hepburn HR, Radloff SE (2011) Biogeography of the dwarf honeybees, Apis andreniformis and Apis florea. Apidologie 42(3), 293-300.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. Int J Climatol 25, 1965–1978.

Hosni EM, Nasser MG, Al-Ashaal SA, Rady MH, Kenawy MA (2020) Modeling current and future global distribution of *Chrysomya bezziana* under changing climate. Scientific Reports 10: 4947. https://doi.org/10.1038/s41598-020-61962-8

Ilyasov RA, Lee ML, Takahashi JI, Kwon HW, Nikolenko AG (2020) A revision of subspecies structure of western honey bee *Apis mellifera*. Saudi J Biol Sci 27(12): 3615-3621.

Jamal, Z.A.; H. F. Abou-Shaara; S. Qamer; M. A. Alotaibi, K. A. Khan; M. F. Khan; M. A. Bashir; A. Hannan; S. N. AL-Kahtani; E. A. Taha; S. I. Anjum; M. Attaullah; G. Raza and M. J. Ansari (2021). Future expansion of small hive beetles, Aethina tumida, towards North Africa and South Europe based on temperature factors using maximum entropy algorithm. Journal of King Saud University – Science,https:// doi.org/ 10.1016/j.jksus.2020. 101242

Le Conte Y, Navajas M (2008) Climate change: impact on honey bee populations and diseases. Revue Scientifique et Technique 27(2): 499-510.

Mogga J, Ruttner F (1988) *Apis florea* in Africa: source of the founder population. Bee World, 69(3), 100-103.

Morse RA, Calderone NW (2000) The value of honey bees as pollinators of US crops in 2000. Bee cult 128(3): 1-15

Mulieri PR, Patitucci LD (2019) Using ecological niche models to describe the geographical distribution of the myiasis-causing *Cochliomyia hominivorax* (Diptera: Calliphoridae) in southern South America. Parasitol Res 118: 1077-1086. https://doi.org/10.1007/s00436-019-06267-0.

Otis GW (1996) Distributions of recently recognized species of honey bees (Hymenoptera: Apidae; Apis) in Asia. J Kansas Entomol Soci 311-333.

Phillips SJ (2017) A Brief Tutorial on Maxent. Available from url: http://biodiversityinformatics. amnh.org/ open_ source/maxent/

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecol Modell 190, 231-259.

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. Ecography 31, 161-175.

Phillips SJ, Dudík M, Schapire RE (2020) Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url: http://biodiversityinformatics.amnh.org/open_source/ maxent/. Accessed on 2020-3-20.

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

Rinderer TE, Oldroyd BP, Wongsiri S, Sylvester HA, De Guzman LI, Stelzer JA, Riggio R M (1995) A morphological comparison of the dwarf honey bees of southeastern Thailand and Palawan, Philippines. Apidologie 26(5), 387-394.

Rinderer TE, Wongsiri S, Kuang B, Liu J, Oldroyd BP, Sylvester HA, de Guzman L (1996) Comparative nest architecture of the dwarf honey bees. J Apic Res 35(1), 19-26.

Ruttner F (1988) Biogeography and taxonomy of honeybees. Springer-Verlag Berlin Heidelberg GmbH, 288. https://doi.org/10.1016/0169-5347(89)90176-6.

Samy AM, Elaagip AH, Kenawy MA, Ayres CF, Peterson AT, Soliman DE (2016) Climate change influences on the global potential distribution of the mosquito *Culex quinquefasciatus*, vector of West Nile virus and lymphatic filariasis. PloS One 11(10): e0163863,https://doi.org/10.1371/journal.pone.0163863

Shebl MA (2017) Discovery of *Apis florea* colonies in northeastern Egypt. Afr Entomol 25(1), 248-249.

Silva DP, Castro ACF, Vilela B, Ong XR, Thomas JC, Alqarni AS, Engel MS, Ascher JS (2020) Colonizing the east and the west: distribution and niche properties of a dwarf Asian honey bee invading Africa, the Middle East, the Malay Peninsula, and Taiwan. Apidologie 51, 1: 75-87.

Southwick EE, Southwick Jr, L (1992) Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. J Econ Entomol 85(3): 621-633

Taha EKA, Al-Abdulsalam M, Al-Kahtani S (2016) Insect pollinators and foraging behavior of honey bees on alfalfa (*Medicago sativa* L.) in Saudi Arabia. J Kansas Entomol Soci 89(1), 92-99.

Yoruk A, Sahinler N (2013) Potential effects of global warming on the honey bee. U Bee J 13(2): 79-87.

Zhang X, He SY, Evans JD, Pettis JS, Yin GF, Chen YP (2012) New evidence that deformed wing virus and black queen cell virus are multi-host pathogens. J Invert Pathol 109(1), 156-159.

نمذجة إنتشار الأنواع لتقييم الغزو المحتمل لنحل العسل القزم *Apis florea* لإفريقيا وأوروبا بعد الدخول إلى مصر مع أخذ تغير المناخ فى الإعتبار

حسام فرج ابو شعرة[١] ، حاتم محمد محفوظ[٢] و أيمن احمد عويس[٣]

[١]قسم وقاية النبات - كلية الزراعة - جامعة دمنهور

[٢]قسم الانتاج النباتي - كلية العلوم الزراعية البيئية - جامعة العريش

[٣]قسم وقاية النبات - كلية الزراعة - جامعة الفيوم

موخراً، غزا نحل العسل القزم *Apis florea* مناطق معينة فى شرق مصر. يعتقد ان النحل القزم سوف ينتشر بشكل كبير فى مناطق اخرى بداخل مصر وخارجها. لذلك الدراسة الحالية تسلط الضوء على إمكانية إنتشار النحل القزم فى مصر وكذلك نحو مناطق اخرى فى أفريقيا وجنوب أوروبا. تم إستخدام برنامج Maxent كبرنامج متخصص فى نمذجة إنتشار الانواع لإجراء هذة الدراسة مع عدد من التغيرات البيئية للظروف الحالية والمستقبلية خلال ٢٠٥٠ و ٢٠٧٠. تنبأت الخرائط الناتجة من الدراسة بالإنتشار المحدود لهذا النوع من النحل نحو جنوب اوروبا تحت ظروف المناخ الحالية، بينما تحت ظروف المناخ المستقبلية تدعم الدراسة إمكانية الإنتشار نحو جنوب وغرب مصر وبشكل خاص خلال السنوات القليلة القادمة. وكذلك توضحت الخرائط المستقبلية إمكانية الإنتشار نحو جنوب اوروبا وبشكل خاص أسبانيا والبرتغال، بنما الإنتشار الكبير فى البلدان الاوروبية الأخرى غير مختمل. وهناك إحتمالية للإنتشار المحدود لهذا النحل فى أفريقيا، بينما المناطق الشمالية أكثر تفضيلاً لهذا النوع من النحل. كذلك تمت مناقشة التبعيات المحتملة لإنتشار هذا النحل فى مناطق مختلفة.