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Historical Review of Mantodea Occurrence in Egypt with Notes about *Eremiaphila* spp. in the Middle East and North Africa

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Abstract

Mantis is charismatic predatory creatures of order Mantodea. They constituted small insects order with about 2500 species. They form one of the most diverse and unique predatory insects on variety of ecosystems and habitats through our planet. Through this work basic information about these insects on Egypt are provided including comprehensive literature survey and notes concerning most important species and specialists through history. Also, the records of occurrence and new species discovered from the Middle East and North Africa were given for genus Eremiaphila.

Keywords: Ehrmann, Desert mantis, Nile, Egypt, Algeria, Saudi Arabia, Iran

INTRODUCTION

Mantids inspired pharaohs since 3000 years ago and ancient records indicated that mantis formed a part of their culture [1]. Mantodea is a small insect order with approximately 2500 species which has been recorded worldwide [2,3]. Praying mantises are predatory insects distributed in tropical and subtropical habitats while few species are found on tempter and cold regions [4]. Several previous studies were discussed the mantis occurrence in Egypt with the last revision of the order was made by Mohammad et al. [5], where they recorded 60 species in 21 genera and 4 families with one new species *Elaea solimani* and one new record *Eremiaphila gigas* Beier, also *Calidomantis ehrenbergi* Werner considered as a new synonym of *Sinaiella sabulosa* Uvarov. The Mantodea of Egypt forms one of unique and sophisticated mantis fauna with the largest number of species in the Palearctic region. Ehrmann discussed the occurrence of a large number of mantis species in the country [6] and he concluded that the geographically historical position of Egypt in the centre of the Old World and the nature of the mantis life cycle with well-preserved ootheca which could travel with the Nile flooding were the main reasons for such diversity. Battiston et al. in their book of mantis in Euro-Mediterranean area, clarified without any doubt that Egypt forms one of the most diverse fauna in the Palearctic region [7].

Eremiaphila is a genus of mantis in the small family Eremiaphilidae of the order Mantodea. The Majority of *Eremiaphila* species were collected from Middle East and North Africa countries. The total number of species of this genus is 70 around the world until now [2,8,9], 60 species of them live in the Middle East and North Africa. A single country of these areas with the highest biodiversity of the genus *Eremiaphila* is Egypt with 30 different species. All species of this genus are truly adapted to arid habitats, the most dominant landscape of the region [7]. *Eremiaphila* is difficult to collect in the field as its species live in remote places of desert areas and usually mimic sand and stones [10].

The aim of this review is to revise all the previous works that concerning this ingesting group of insects in Egypt and giving account on one of its genera (Genus: *Eremiaphila*) through the Middle East and North Africa.

Occurrence of Mantodea in Egypt

Early days

There are many previous literatures that have dealt with mantis occurrence in Egypt, which has extended through four centuries started early on the 18th century by Forskal [11], who described *Sphodromantis viridis* and *Gryllus monstrosus* for the first time from Alexandria on the Mediterranean Coast. After that, Savigny adduced 20 forms of mantis occurring through the country during the French campaign in Egypt and gave full drawings for them [12]. These forms received the attention of the scientists as they were identified by Audouin [13], diagnosed by Krauss [14] and later re-identified by Boisard et al. [15].

The first catalog of Mantodea was published through the second half of the 19th century by Saussure where family Mantidae was divided into three tribes: Acanthopsini, Eremiaphilini and Mantini [16,17]. Moreover, Saussure gave the diagnostic characters to each species including 26 species reported from the Egyptian fauna. Through his trips to Egypt, Palestine and Turkish, Costa recorded two species of mantis: *Blepharopsis mendica* Fabricius and *Eremiaphila khamsin* Lefèbvre from the Egyptian fauna [18]. In 1880 *Eremiaphila aristidis* was discovered and described from Suez [19]. Westwood revised all species of family Mantidae that have been recorded until 1889 through the globe and added the type locality of each species including all previously mentioned species of Egyptian fauna [20].

20th century

At the beginning of 20th century, the old world mantis specimens housed in the Academy of Natural Sciences of Philadelphia and the United States National Museum were examined by Rehn, who recorded 34 species and described 4 new species [21]. In this work *Eremiaphila bove* Saussure and *Sphodromantis bioculata* Burmeister were reported from Egypt. Again, in another study, Rehn recorded *Heterochaeta pantherina* Saussure from the Egyptian fauna [22]. Werner introduced a series of studies on mantodea of Egypt (1905-1928). In 1905, Orthoptera fauna-Mantodea specimens were usually included in Orthoptera and Dermeptera studies for several years and by several authors-of El-Mokattam hill near Cairo was studied and 5 species of mantis: *Blepharopsis mendica* Fabricius, *Centromantis pyramidum* Werner, *Empusa egena* Charpentier, *Mantis relagiosa* Linne and *Sphdromantis viridis* Werner were identified [23]. While in 1906 *Eremiaphila klunzingeri* Werner was described as a new species from Elqoseir on the Red Sea coast through the examination of the African specimens in Stuttgart museum of natural history [24]. After that, the occurrence of *Calidomantis ehrenbergi* Werner was insured in Egypt [25].

Innes revised the Egyptian Orthoptera and recognized 28 species of mantis, classified in three tribes and 11 genera: Empusini (*Blepharopsis and Empusa*); Mantini (*Ameles, Fischeria, Iris, Mantis, Miomantis and Sphdromantis*); and Orthodrini (*Centromantis, Eremiaphila* and *Heteronutarsus*) [26].

Through the examination of the exotic mantis specimens collected from all over the world, Giglio-Tos [27] added *Paroxyophthalmus collaris* Saussure to the Egyptian Mantodea. The same author revised the subfamily Eremiaphilinae, divided it into 10 groups with 184 species belonging to 29 genera and reported 22 species from Egypt [28].

Mantodea specimens in the collection of Ministry of Agriculture were studied by Uvarov, who identified 12 species and described *Sinaiella nebulosa* Uvarov for the first time from North Sinai [29]. The same author re-examined the specimens of Orthoptera which were collected from Sinai by Bodenheimer and Theodor in 1927 and reported 3 *Eremiaphila* spp. including *Eremiaphila rufipennis* Uvarov as a new species [30]. In the same year, Capra [31] examined the Orthoptera and Dermeptera specimens that collected by Italian Geographical Society during their expedition to Giababub oasis on Egyptian Libyan border. He recorded 5 mantis species with *Ealea gastrio* as new species. Uvarov revised the genus *Iris* and described *Iris coeca* Uvarov from Egypt [32]. Moreover, *Elaea gestroi* Capra, *Eremiaphila rufipennis* Uvarov, *Iris coeca* Uvarov, *Mantis religiosa* Linné and *Sphodromantis viridis* Forskal were identified from Siwa oasis by Uvarov [33].

Beier [34] in his study of the subfamilies Sibyllinae and Empusinae reported 7 species of the Empusin crown mantis genera *Empusa*, *Blepharopsis* and *Hypsicorypha* from Egypt. After that, the same author gave a valuable contribution for mantis taxonomy in studying subfamily Mantinae and divided it into 12 tribes, constructed keys to tribes and genera, and gave species list with their geographical distribution [35]. Orthoptera of Palestine and Sinai were surveyed by Bodenheimer [36] who recorded 12 species of mantis in three subfamilies: Empusinae, Eremiaphilinae and Mantininae.

At the second half of the 20th century, Ebner [37] gave the taxonomic characters and geographical distribution of two rare Egyptian species: *Empusa hedenborgii* Stal, and *Heteronutarsus aegyptiacus* Lefebvre. Genus Tarachodes was divided into five subgenera based on the morphology of male genitalia and *Tarachodes* (Chiropacha) *gilvus* Charpentier was recorded from Egypt for the first time by Beier [38]. Beier [39] considered Mantodea as an order not as a family under Dictyoptera with 8 families: Amorphoscelidae, Chaeteessidae, Empusidae, Eremiaphilidae, Hymenopodidae, Mantidae, Mantoididae and Metallyticidae and this formed a revolutionary step on studying mantis taxonomy.

The presence of *Rivetina baetica* Rambur in Egypt was indicated by Kaltenbach [40] who revised species of *Ameles* and *Empusa* in the Egyptian fauna in 1963. The occurrence of *Empusa fasciata* Brullé, *Iris oratoria* Linné and *Mantis religiosa* Linné were confirmed in the Egyptian fauna by Kaltenbach [41]. In 1979, Ibrahim [42] studied the Mantodea of Egypt and reported 36 species in family Mantidae. In this study she gave a long description for each of them, constructed identification keys for genera and species within each genus. Also, she made a good study for two mantis species biology and morphology. La Greca and Lombardo [43] revised species of genus *Rivetina* Berland and Chopard on Mediterranean and Western Asia in 1982 using male genitalia as a main identification character; also they reported *Rivetina baetica* tinuidentata as a new subspecies from Egypt.

Roy [44] reviewed all works on the systematics of order Mantodea since 1798 and commented on some taxonomic problems of the order. In another study, Roy [45] analysed the biogeography of African mantises including 880 species within 156 genera and clarified that Africa occupies the top position globally for mantids with the greatest generic diversity is in the Eastern part. Depending on the morphology of the head capsule *Sphodromantis* and *Hierodula* were considered as two different genera and *Hierodula* was excluded from the Egyptian Mantodea by Bragg [46].

"Reinhard Ehrmann's catalog" impact of the most important figure of the period

Ehrmann is one of the most active entomologists in the field of Mantodea taxonomy where he gave a series of contributions started in 1996 by a description of *Severinia ullrichi* Ehrmann as a new species from Alexandria and recording of 46 species of mantis from Egypt [6]. Moreover, he discussed the main reasons for the existence of such a number of species in the Egyptian fauna and regarded this phenomenon to the stable and well-preserved mantis ootheca that are usually attached to tree branches and other hard objects which are easily transported from many parts of the world to Egypt through commerce, nomadic bedouin and the Nile flood. Order Mantodea was reclassified into 13 families: Acanthopidae with 51 species, Amorphoscelidae with 84 species, Empusidae with 51 species, Eremiaphilidae with 70 species, Hymenopodidae with 225 species, Iridopterygidae with 92 species, Liturgusidae with 64 species, Mantidae with 941 species, Sibyllidae with 14 species, Tarachodidae with 210 species, Thespidae with 190 species, Toxoderidae with 42 species and Vatidae with 258 species by Ehrmann in 1997 [47].

At the beginning of the 21st century, Ehrmann [48] indicated that order Mantodea comprising 2300 species within 435 genera around the world and clarified that variation among Mantodea is very clear in colors, sizes and wings coloration. In addition, the same author gave important information about ecology, distribution, type locality and field photos of the most common species around the world [2]. In 2005 a bibliography of all literature published about Mantodea since 1658 until 2005 was provided by Ehrmann [49].

Otte & Spearman in their catalogue of the world Mantodea, classified the order into 14 families, 47 subfamilies, 51 tribes, 446 genera and 2425 species where he gave synonyms and citation of each species [3]. Roy created *Dilatempuas* as a new genus of family Empusidae [50]. He moved 5 species from genus *Empusa* Illiger to this new genus including the Egyptian species Egyptiaca Giglio-Tos. Meanwhile, *Eremiaphila berndstiewi* Stiewi was described as a new species from Hurghada [8].

New discoveries and trends

The population density and biodiversity of some Mantis fauna in El-Fayoum governorate, was estimated by using mark release recapture technique. The study that show how the population of mantis decreases through the year from the flourished spring to very few individuals in the end of the autumn as the mantis has only one generation per year [51]. Battiston et al. stated that Egypt with at least 55 different species "it" forms the most divers country of the region and regarded this richness to the presence of the Nile valley as along, green strip that crosses the yellow sands of the desert that permit tropical animals to cross the Sahara desert creating channel for biodiversity [7]. Nasser introduced the first chemical taxonomic study on mantodea species collected from the Egyptian fauna [52]. The cuticular hydrocarbons profiles of mantis species that were obtained in this study can be used for the confirmation of

species occurrence in the faunal works also it could help in studying mantis phylogeny. Moreover, a good contribution in studying Mantodea of Egypt was made by Mohamed et al. who reported 60 species belonging to 21 genera and 4 families: Empusidae, Eremiaphilidae, Mantidae and Tarachodidae [5]. They also discovered a new species *Elaea solimani* from Baharia Oasis on Western desert, and gave species list with their world geographical distribution.

Eremiaphila in Middle East and North Africa

***Eremiaphila* in North Africa**

In Egypt, Lefebvre described 12 new species: *E. anubis*, *E. audouini, E. bovei, E. hebraica, E. hralili, E. khamsin* and *E. zetterstedti* from Suez; *E. cerisyi, E. kheychi, E. luxori* from Luxor in Upper Nile Valley; *E. savignyi, E. typhon* from Baharia Oasis in Western desert [53]. At the same year *E. lefebvrii* Burmeister was described for the first time [54]. After that, *E. brevipennis* Saussure and *E. dentate* Saussure were described from Nuba in Upper Nile Valley [16]. The occurrence of *E. khamsin* Lefèbvre in Egypt was reported by Costa through his biological trips to Egypt, Palestine and Turkish [18]. *E. aristidis* Lucas was described as a new species from Suez [19]. In addition, Rehn recorded *E. bovei* Lefebvre from Egypt through the examination of the old world mantis specimens housed in the Academy of Natural Sciences of Philadelphia and the United States National Museum [21]. Werner described two new species of *Eremiaphila* from Lower Nile Valley: *E. heluanensis* Werner from Helwan and *E. pyramidum* Werner from Giza [55]. The same author described *E. klunzingeri* Werner from Elqoseir at Red Sea Coast [24]. Moreover, *E. andresi* Werner and *E. cairina* Giglio-Tos were described as new species from Dekhla Oasis and Cairo [56,57]. The occurrence of 21 species of genus *Eremiaphila* was indicated in Egypt [28]. *E. rufipennis* Uvarov was described for the first time from Sinai [30]. Ibrahim reported the presence of 17 *Eremiaphila* spp. in the Egyptian fauna [42]. Ehrmann indicated that the total number of species in genus *Eremiaphila* in Egypt is 28 species [2]. After that, Stiewe discovered *E. berndstiewi* Stiewe from Hurghada at Red Sea Coast and reported that this amazing species has large fore legs, femora with 4 discoidal and 4 external spine, male provided with apical spines the internal one is smaller than external [8]. At last, Mohamed et al. through the study of the Egyptian Mantodea clarified that the number of species of genus *Eremiaphila* in Egypt is 30 species [5]. In addition, they reported the type locality, diagnosis, world distribution and specimens examined for each species of genus *Eremiaphila*.

Algeria comes next in the number of *Eremiaphila* spp., *E. barbara* Brisout, *E. denticollis* Lucas, *E. numida* Saussure, *E. spinulosa* Krauss and *E. foureaui* Bolivar were described as new species from its fauna [17,58-61]. In addition, Chopard who is considered as one of the most greatest entomologists who interested with genus *Eremiaphila* described five new species from the country during the period (1934-1954): *E. laeviceps; E. monodi, E. mzabi* and *E. tuberculifera; E. pierrei* [62-64]. Meanwhile, the occurrence of *E. typhon* Lefebvre in Algerian fauna was reported by Ehrmann in his important catalogue of order Mantodea around the world [2] and confirmed by Battiston et al. [7] and Caesar et al. [65].

Genus *Eremiaphila* is represented by 6 species in Libya as *E. rotundipennis* Kirby and *E. rohlfsi* Werner were described as new species [23,66]; *E. pyramidum* Werner, *E. andresi* Werner, *E. laeviceps* Chopard and *E. savignyi* Lefebvre were reported from its fauna [2,28].

The occurrence of *Eremiaphila* spp. in Morocco and Tunisia was reported by Ehrmann [2] and Battiston et al. [7]. They indicated the presence of *E. denticollis* Lucas in both Morocco and Tunisia; *E. murati* Chopard, *E. rufula* Chopard and *E. reticulata* Chopard in Morocco. In addition they confirmed the presence of *E. denticollis tunetana* Werner in Tunisia which was described as a new species from its fauna [55].

Eremiaphila in the Middle East

E. arabica Saussure (1871), *E. braueri* Krauss (1902) and *E. cycloptera* Uvarov (1939) were described as new species from Saudi Arabia [16,67-68]. After that, *E. burmeisteri* Saussure, *E. genei* Lefebvre [28,68]; *E. cerisy* Lefebvre, *E. savignyi* Lefebvre and *E. typhon* Lefebvre [2,69-70] were recorded from Saudi Arabian fauna.

In the Sudan, 5 new species of genus *Eremiaphila* were described from its fauna: *E. hedenborgii* Stal, *E. cordofan* Werner, *E. wettsteini* Werner, *E. werneri* Giglio-Tos and *E. gigas* Beier [57,71-74].

In 1939, *E. yemenita* Uvarov was described as a new species in Yemen [68]; the occurrence of *E. arabica* Saussure, *E. genei* Lefebvre, *E. braueri* Krauss and *E. Khamsin* Lefebvre were reported from its fauna [2].

E. persica persica Werner and *E. persica sjodstedti* Werner were described as new species from Iran [23,75]. Moreover, *E. cerisy* Lefebevre, *E. genei* Lefebvre and *E. turcica* Westwood were recorded from Iranian fauna [2,7,76].

In Jordan, two new species were described: *E. ammonita* Uvarov from Amman [77] and *E. uvarovi* Bodenheimer from Ma'an [78]. In addition, *E. braueri* Krauss and *E. genei* Lefebvre were recorded in Jordan [2,7,65,79].

From Iraq, Uvarov described *E. fraseri* Uvarov as a new species from the country [80]. Also, the occurrence of *E. turcica* Westwood, *E. cerisy* Lefebvre and *E. andresi* Werner were confirmed in Iraq fauna [2,7,65].

Mantodea of Turkey was studied by Demirsoy, who gave the general characters of its families, genera and species and provided identification keys for them [81]. He reported the occurrence of *E. turcica* Westwood, *E. burmeisteri* Saussure, *E. genei* Lefebvre. *E. burmeisteri* Saussure was considered as a synonym of *E. genei* Lefebvre, also *E. persica persica* Werner was reported in Turkey [2]. After that, *E. dagi* Dongalar was described as a new species from this fauna [9].

The presence of *E. braueri* Krauss and *E. cerisy* Lefebvre was reported in United Arab Emirates [2]. Saji and Al Dhaheri studied the diversity, abundance and seasonality of ground dwelling invertebrate's species in the eastern region of Abu Dhabi Emirate; through his study they reported the occurrence of *E. genei* Lefebvre from this country [82].

In Palestine, Giglio-Tos reported the occurrence of *E. brunneri* Werner from the country [28]. Abu-Dannoun & Katbeh-Bader reported the presence of *E. ammonita* Uvarov and *E. uvarovi* Bodenheimer from this fauna [79]. *E. arabica* Saussure and *E. brunneri* Werner were added to fauna of Israel [2,7].

In Oman, Kaltenbach reported the occurrence of *E. braueri* Krauss during the study of Mantodea in Saudi Arabia [70]. Also, the presence of *E. cerisy* Lefebvre was indicated in Oman fauna [2,65].

Genus *Eremiaphila* is represented by only two species in both Syria and Lebanon. *E. genei* was described as a new species from Syria by Lefebvre [53] and *E.* typhon Lefebvre was recorded from its fauna [2,7,28,65]. On the other hand, the occurrence of *E. turcica* Westwood and *E. genei* Lefebvre were confirmed in Lebanon [65].

In Kuwait, Uvarov reported only one species: *E. braueri* Krauss from the state [68]. There are no previous literatures discussing the existence of any species of genus *Eremiaphila* from Qatar and Bahrain, but later on it was reported that Qatar has *E. braueri* Krauss [83].

ANALYSIS AND INFERENCE

By analyzing the work on Mantodea of Egypt through history (Figure 1), we can divide the intervals into six stages. During the period of 1750-1799, the first stage, Forskal [11] recorded only two mantis species from Egypt. The second stage was the golden era extended between 1800-1849; where 14 new species were described from Egyptian fauna. The authors of these species like Savigny [12] and Audouin [13], were not only interested in Mantodea but also with many other creatures. The third stage was extended between the Middle of the nineteenth century to the beginning of 20th century where 4 new species were discovered as a new species from Egypt. Costa [18], Westwood [20], Krauss [14,60,67], Lucas [19,59] and Saussure [16,17] were some notable and remarkable scientists of that period. The fourth stage which extended from 1900-1949, at which 10 new species were described from Egypt. Werner [23-25,55,56,72,73,75], Giglio-Tos [27,28,57], Uvarov [29,30,32,33,68,77,80] were the most important entomologists "where" concerning the study of Mantodea in Egypt in this period; Capra [31] and Bodenheimer [36,78] were also some notable scientists of this period. The fifth stage was extended between the middle of the 20th century to the beginning of 21th century. Only one new species was described from Egypt through this period. The sixth stage was extended from 2000 until now, two species recorded as new species from Egyptian Fauna. Ehrmann [26,47-49] was on the top of scientist in this period because he made a catalogue about Mantodea of the world including Egypt. Through this period new technique (cuticle hydrocarbon) was used in study taxonomy of Mantodea in Egypt.

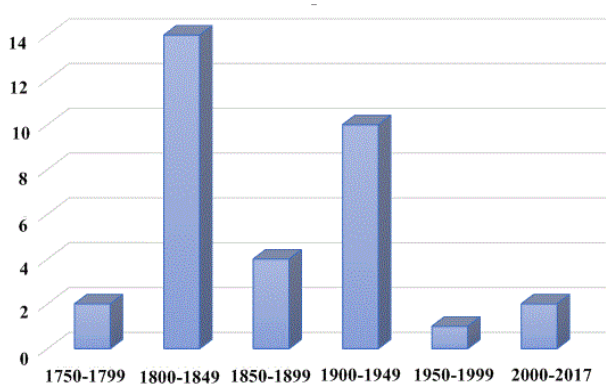

Figure 1: The graph shows new mantis species described from Egypt through 50 year intervals between1750-2017; numbers of new mantis species (y-axis) and years (x-axis)

On the other hand, analysis of the work on Mantodea concerning the new mantis discovered in the different Egyptian ecological zones (Figure 2) elucidated that Eastern desert with 9 new species ranked the first ecological zone in the number of the described new species. Western desert, Lower Nile Valley (including delta), Coastal strip and Upper Nile Valley with 4 new species for each of them come in the second rank, followed by Sinai with 2 new species in the third rank. Meanwhile, there wasn't any new species described from Fayoum Basin or Gebel Elba. Finally, the Mantodea fauna of Egypt constituted of 60 species divided into 21 genera under 4 families [5].

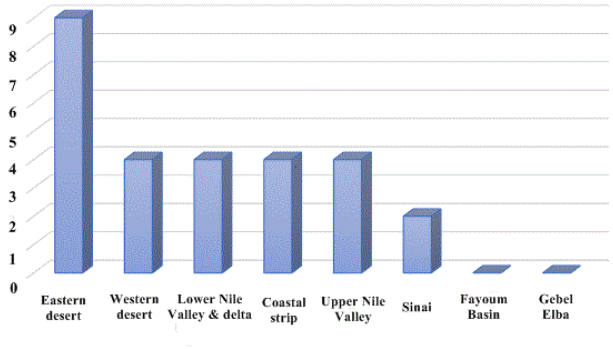

Figure 2: The graph shows the number of new mantis species which discovered in the different ecological zones in Egypt; number of new mantis species (y-axis) and Ecological Zones (x-axis). (Ecological zones of Egypt according to El-Hawagry and Gilbert [84])

By analysing the previous works concerning the new species of genus *Eremiaphila* that discovered from 13 countries of the Middle East and North Africa through history (Figure 3), we find that Egypt has the largest number of new species reported (24 species). The second country that follows Egypt in the number of new species recorded is Algeria with 10 new species. The third country is the Sudan with 5 new species, and 3 new species were described from Saudi Arabian fauna. Turkey, Iran, Jordan and Libya have 2 new species for each of them; Tunisia, Syria, Israel, Iraq and Yemen with only one species.

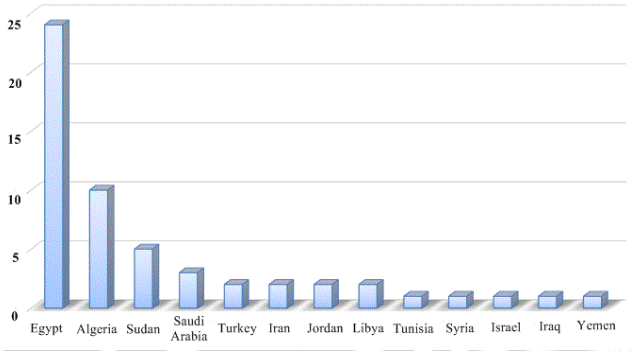

Figure 3: The graph shows the number of new species of genus Eremiaphila that were discovered from 13 countries of Middle East and North Africa; number of new species discovered (y-axis) and countries (x-axis)

Concerning the actual number of species in genus *Eremiaphila* from each country of Middle East and North Africa (Figure 4), we find that Egypt is ranked the first in the diversity of genus *Eremiaphila* with 30 recorded species. Battiston et al. regarded the high diversity of *Eremiaphila* in Egypt to the separation of the desert by Nile into small different micro-habitat [7]. The second country that follows Egypt in the diversity of this genus is Algeria with 11 different species [2]. The third country with diversification of genus *Eremiaphila* is Saudi Arabia with 8 different species. Six different species are distributed in Libyan fauna. Yemen, Sudan and Iran have 5 different species from each of them. Jordan, Iraq, Turkey and Morocco have four different species of genus *Eremiaphila* in their fauna. Palestine, United Arab Emirates, Israel, Oman, Tunisia, Syria and Lebanon have 2 different species in each of them. Qatar and Kuwait are the least diversified countries for this genus with only one species. The only country that doesn't contain any species of *Eremiaphila* is Bahrain.

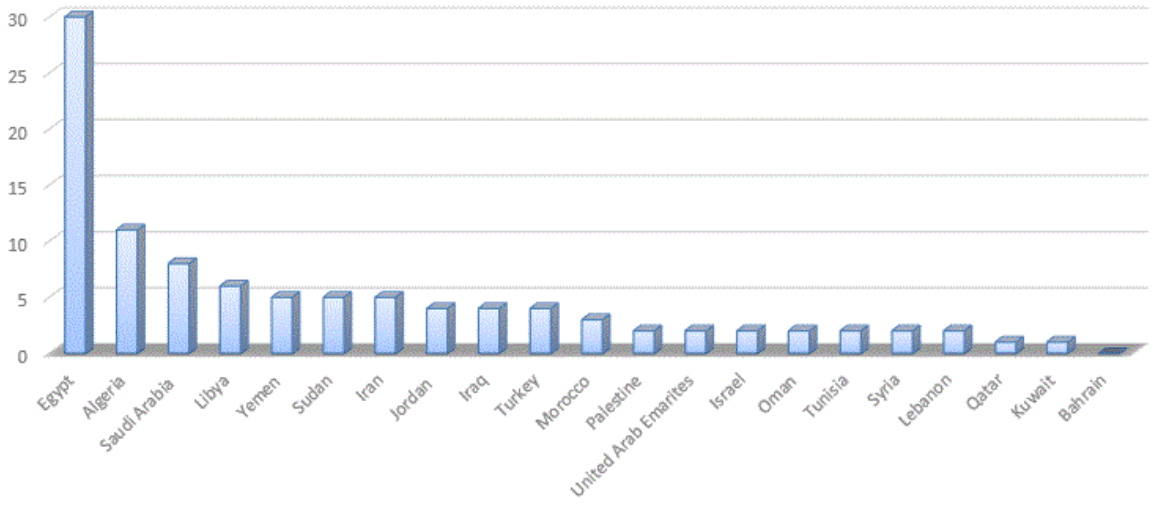

Figure 4: The graph shows the actual number of species in genus Eremiaphila from each country of Middle East and North Africa; number of species (y-axis) and countries (x-axis)

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