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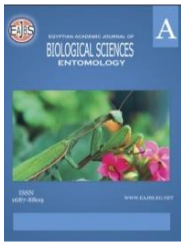

Studying the Interaction Between *Asphondylia punica* and Its Host Plant, *Atriplex halimus*, and Predicting Their Potential Geographic Distribution in Egypt by Using Maxent Technique

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ABSTRACT

Galls and their inducing insects represent one of the most challenges that facing entomologists because of their unique life history and the highly characteristic gall structure. Gall-inducing insects and their distributions in Egypt of little studies which depend on few researchers from countries of Europe during their scientific journeys. *Asphondylia punica* (Diptera: Cecidomyiidae) is associated with one of the most important medicinal plants, the *Atriplex halimus* (Chenopodiaceae). *A. punica* induces fusiform swellings galls on the stem *of A. halimus* with multiple chambers. The interaction between the gall inducer *Asphondylia punica* and its host plant *A. halimus were studied.* The results indicated that there was a significant correlation between the number of galls per plant and the plant cover but there was no correlation between the number of galls per plant and altitude. The predicted distributions of *Asphondylia punica* in Egypt were done by using MaxEnt technique. The results showed that the prediction distribution of *Asphondylia punica* and its host plant *Atriplex halimus* is concentrated in Mediterranean coastal regions.

INTRODUCTION

Gall inducers are about 13,000 known species in the world, approximately 2% of total insect species (Dreger-Jauffret & Shorthouse, 1992; Raman *et al*., 2005). The prominent species in the order Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Thysanoptera are amongst the gall-inducing insects (Shorthouse and Rohfritsch, 1992, Maia, 2006, Price, 2005). Among these, Diptera and Hymenoptera are the largest numbers of gall-inducing species (Espirito-Santo and Fernandes, 2007). Gall-inducing insects are capable of changing the growth pattern of a host plant, alter the vegetative tissue structure, and lead the host to develop a nutrient-rich, non-small food supply, along with an environmentally insulated protective structure (Price *et al.,* 1986 &1987).

Galls are normal plant structures, which grow modified, invariably symmetrical, due to the messages of the inducing insects (Mani 1964, Raman 2011). The larval stages of gall inducer live in them and provide nourishment and protection for a certain period of time. The biology and ecology of the inductive insect have a strong impact on the morphology and physiology of the plant (Shorthouse and Rohfritsch 1992, Raman, *et al.,* 2005).

Gall-inducing insects have several ecological services including pollination (Kjellberg *et al.,* 2005 and Borges 2015). Some of gall midge species are economically important, it can cause damage to agricultural plants (Darvas *et al.,* 2000) and to forest trees (Skuhravá & Roques 2000; Drooz 1985). Some galls have medicinal values, they contain tanins that are used for tanning in (Gerling, *et al.,* 1976). Also, Galls are used commercially as dye hair and other tissues in addition to written ink in the 17th century (Fernandes and Martins 1985). Gall save the gall-inducing insect larvae against climatic changes and natural enemies and provide it with nutation (Raman *et al.,* 2005; Bailey *et al.,* 2009).

A. halimus used as forage for sheep, goats, cattle, and camels (Khattab, 2007). It is used for the treatment of syphilis (Rolleston, 1942). The leaves are used to treat heart diseases and diabetes and rheumatism (Said *et al*., 2002). The ash is used as an alkali to make soap (Uphof, 1968). Extracts material of *A. halimus* is used as antibacterial activity against various Gram-positive and negative pathogenic bacteria (Abdel Rahman *et al.,* 2011). Endophytic fungi isolated from *A. halimus* showed antibiotic activity (Peláez *et al.,* 1998).

Large galls on the stems of *Atriplex halimus* L. (Chenopodiaceae) formed by larvae of *Asphondylia punica*. Small galls on Atriplax halimus were discovered in Dorchin *et al.,* (2014) redescribed the gall inducer, and gave *A. conglomerata* a junior synonym as instead of *A. punica*. It is also collected from Alexandria, El-Amria district (Elsayed *et al.,* 2015). It is found in some countries such as Italy (Sicily) (Skuhravá *et al.,* 2007), Canary Islands (Graham & Gijswijt 1998), Greece (Crete) (Skuhravá, 1996; Skuhravá & Skuhravý 1997), and Libya, Tunisia Israel, and Egypt (Debski, 1918).

Species dispersion models depend on the connection between species distribution and the ecological factors variables determining suitable habitats and limiting barriers. Likewise, these methodologies can be helpful to predict suitable habitats for species in regions where their distribution completely unknown (Guisan and Thuiller, 2005). Species distribution models are generally useful in several ecological, biological, and biogeographical applications to predict species distributions in the past, now and in the future (Guisan and Thuiller, 2005). Model investigations are very important in biological studies; Its predictive abilities shed light on many issues, such as raising protected species distribution or possible expansion of invasive species (Beck, 2013; Fourcade *et al.,* 2014). MaxEnt technique is popular due to its easy to use (Philips and Elith, 2013). The MaxEnt technique can be used to predict the potential distribution of a target species when it satisfies the maximum entropy under different conditions, it can achieve highly accurate results with available appearance data only. Specifically, MaxEnt analyzes the location data to predict the potential distribution of the target species, dependent on environmental variables. (Phillips *et al*., 2006).

Over the world, several studies were done by using MaxEnt, It has been used to predict the potential distribution of *Phenacoccus solenopsis* in India (Kumar et al., 2014). Also, in Europe, distributions of large pine weevil and horse-chestnut leaf miner were predicted (Barredo *et al*., 2015). However, in South Korea, apart from one study that predicted the potential distribution of the *Pochazia shantungensis*, a planthopper (Kim *et al*., 2015).

In Egypt, some studies were performed using species distribution models for predicting the potential geographic distribution of several species (El Alqamy *et al.,* 2010, Kamel *et al.,* 2012).

The aim of this work was to study the interactions between the gall-inducing insects *Asphondylia punica* and their host plants *A. halimus* and to predict their potential geographic distribution in Egypt by using maxent technique.

MATERIALS AND METHODS

Study Area:

The current study was conducted in some regions of the Mediterranean coastal land. The chosen sampling sites for *A. halimus* were Merghem, El-tafaroa, Al hawaria, Burg El-arab, El-gharbaniat, El- amria, and Abd-elkader (Fig. 1). The study sites were visited periodically in the period from Feb. 2019 to Jun. 2020, once every two months. Egypt is a large country and its territory occupies 1,010,000 km^2 and represents the westernmost part of the Middle East or Near East. Egypt's north coast extends from Sallum for approximately 970 km east to Rafah, with an approximate width of 15-20 km in a north-south direction (El-Hadidi, 1981). Egypt has its Mediterranean coastline divided into four areas: Eastern Coast (from El-Arish to Port Said), North (Bardawil, Southern, Manzala and Burullus) and Deltaic (Mariout), Central (Alexandria) and Western (from Al-Agami to Salloum); and Southwest (Mariout), Edka, North (Southern); and Southwest (Eastern) (El-Hadidi, 1981). 2,426 plant species were recorded in Egypt (Täckholm 1974). The Mediterranean coast region has about 1083 plant species and an annual rainfall of 20-100 mm was received (El Hadidi and Hosni, 1996). Only about 255 species recorded from this territory, 18 known species are endemic (El Hadidi and Hosni, 1996). Regions of the Mediterranean coast are moderate to warm temperatures and little precipitations recorded in the winter months (Osman and El-Garf, 2015).

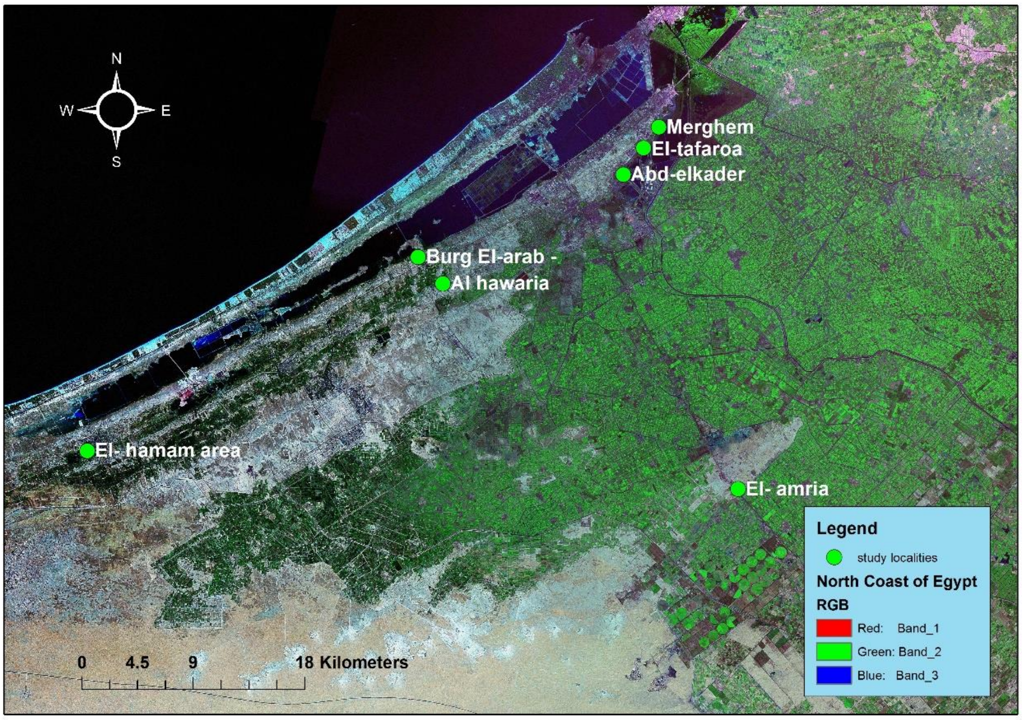

Fig. 1. Location map showing the sampling sites in some regions of Egypt, especially the Mediterranean coast. (Map source: IESR, GIS unit & google map - https://www.google.com.eg/maps/@30.9620935,29.5970038,11z).

Study Plants:

Atriplex halimus (Chenopodiaceae) is a straight, perennial, shrub, reached to 3 m in height and bark being silvery-white in colour. It has numerous kidney-shaped fruits, 3.5-4 x 5-6 mm. It has brown to dark brown 1.5 mm seeds (Flora of Pakistan, 2018). It has 10-30 mm long and 5-20 mm wide alternate leaves and has yellowish or green flowers (Tutin *et al*., 1993). It lost some leaves during the warm dry summers (Walker, 2014). The recorded locations of *A. halimus* in Egypt is shown in (Table 1).

Table 1: The recorded locations of *A. halimus* in Egypt

No.	Location	Coordinates		References
		latitude	longitude	
1	Nobaria	30.147114	30.60701	Hegazi, E. M et al., (1980)
2	Abo-Kir area (22 km east of Alexandria)	31.3164	30.0617	Hegazi, E. M et al., (1980)
3	Fayoum	29.3039	30.8453	Al-Sherif, E. A.et al., (2018)
4	Mariut Lake	31.147	29.3039	Zahran, M. A., & Willis, A. J. (2008)
5	Helwan Desert	29.9036	31.4050	Zahran, M. A., & Willis, A. J. (2008)
6	Gebel Ugma sinai	29.3741	33.6807	Zahran, M. A., & Willis, A. J. (2008)
7	Wadi El-Natrun	30.7367	30.3477	Abd El-Ghani, M. M., et al., (2015)
8	Burullus	31.417	30.8283	Shaltout, K. H., & Al-Sodany, Y. M. (2008)
9	Sallum	31.56667	25.15	Amer, W. M., & Amany, S. A. (2014)
10	Rosetta	31.4	30.41667	Amer, W. M., & Amany, S. A. (2014)
11	El-Mahmoudia	31.13333	30.2	Amer, W. M., & Amany, S. A. (2014)
12	221.5 km Alex- Matruh	31.06667	29.56667	Amer, W. M., & Amany, S. A. (2014)
13	227 km, Alex- Matruh	31.08333	29.63333	Amer, W. M., & Amany, S. A. (2014)
14	237 km, Alex- Matruh	31.11667	29.75	Amer, W. M., & Amany, S. A. (2014)
15	Abu Qir	31.31667	30.06667	Amer, W. M., & Amany, S. A. (2014)
16	Gamasa	31.43333	31.53333	Amer, W. M., & Amany, S. A. (2014)
17	140 km, Alex- Matruh	30.83333	28.2	Amer, W. M., & Amany, S. A. (2014)
18	10 km from El-Alamein	30.81667	28.98333	Amer, W. M., & Amany, S. A. (2014)
19	El-Busseili	31.33333	30.41667	Amer, W. M., & Amany, S. A. (2014)
20	Maadi desert	29.96667	31.25	Amer, W. M., & Amany, S. A. (2014)
21	Wadi Digla	29.95	31.33333	Amer, W. M., & Amany, S. A. (2014)
22	Wadi Digla	29.93333	31.48333	Amer, W. M., & Amany, S. A. (2014)
23	Wadi Hof site1	29.86667	31.41667	Amer, W. M., & Amany, S. A. (2014)
24	Wadi Haggag, Sinai	28.86667	34.41667	Amer, W. M., & Amany, S. A. (2014)
25	Ain Sokhna S. of Suez	29.61667	32.31667	Amer, W. M., & Amany, S. A. (2014)
26	Ain Sokhna S. of Suez site 2	29.61667	32.31667	Amer, W. M., & Amany, S. A. (2014)
27	206 km Alex- Matruh	30.88333	29.4	Amer, W. M., & Amany, S. A. (2014)
28	26 km east of Matruh	31.23333	27.53333	Amer, W. M., & Amany, S. A. (2014)
29	Abu Matamir	30.9	30.16667	Amer, W. M., & Amany, S. A. (2014)
30	Sidi Krer	31.16667	29.63333	Amer, W. M., & Amany, S. A. (2014)
31	11 km east of Sallum	31.53333	25.33333	Amer, W. M., & Amany, S. A. (2014)
32	Idko	31.3	30.3	Amer, W. M., & Amany, S. A. (2014)
33	Ras El Hekma	31.25	27.86667	Amer, W. M., & Amany, S. A. (2014)
34	Gamasa	31.56667	31.53333	Amer, W. M., & Amany, S. A. (2014)
35	Sinai	31.4	34.2	Amer, W. M., & Amany, S. A. (2014)
36	Omayed area	30.822	29.196	Salem, B. (2014)

Samples Collection and Identification:

Field collections of galls were done from some regions of the Mediterranean coast. Some of the immature stages of the insect inside the galls were collected from the field and reared in the laboratory at the Faculty of Science, Al Azhar University to get emerged adults for identification. In 70 % ethanol for morphological analysis Larvae, pupas, and adults from gall midges have been preserved. Width, length, and height of each plant within the sample were measured using a tape meter, in addition, the number of galls on different parts of the plant was counted. Plant samples were identified according to (Boulos, 1999).

Data Analysis:

All data were analyzed by using SPSS computer package (PASW Statistics Ver.20). Correlation between altitude, plant size, and the number of galls per plant was performed by using Pearson correlation test. Also, the mean number of galls per plant was compared between different localities by using a one-way ANOVA test.

Mapping and Predicting Distributions of Plant Species:

Distributional data for the presence of *Atriplex halimus* reported by using GPS (Garmin XL 12). Visiting for the study localities occurred regularly during the life cycle of the plant gall formation, providing information on the presence/absence of the species. The prediction of the potential geographic distribution of gall-inducing insects was built by using MaxEnt technique with environmental variable layers for the study area, such as altitude, temperature, moisture, etc (Phillips *et al.,* 2004, 2006).

Environmental Data of The Model:

The model used many data sets as raster grids. Environmental predictors were classified into climatic data and topographical variables. The WorldClim data set (Hijmans *et al*., 2005; http:/www.worldclim.org/bioclim.htm) provided 19 bioclimatic variables (Table 1) that were more biologically meaningous in determining an eco-physiological tolerance of a species (Graham et al., 2006). The topographical data consists of a series of data include altitude. The collection of partial data (~1Km) from the Shuttle Radar Topography Mission (SRTM) was used with the Altitude raster. Additionally, we acquired review distributional information for *A. halimus* from the Mediterranean basin database and distributed writing next to our solid observational information.

Table 1: The WorldClim climatic variable names

	Variable Definition
Bio1	Annual Mean Temperature.
Bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp).
Bio3	Isothermality (P2/P7) (* 100).
Bio4	Temperature Seasonality (standard deviation *100).
Bio5	Max Temperature of Warmest Month.
Bio6	Min Temperature of Coldest Month.
Bio7	Temperature Annual Range (P5-P6).
Bio8	Mean Temperature of Wettest Quarter.
Bio9	Mean Temperature of Driest Quarter.
Bio10	Mean Temperature of Warmest Quarter.
Bio11	Mean Temperature of Coldest Quarter.
Bio12	Annual Precipitation.
Bio13	Precipitation of Wettest Month.
Bio14	Precipitation of Driest Month.
Bio15	Precipitation Seasonality (Coefficient of Variation).
Bio16	Precipitation of Wettest Quarter.
Bio17	Precipitation of Driest Quarter.
Bio18	Precipitation of Warmest Quarter.
Bio19	Precipitation of Coldest Quarter.

Statistical Validation of The Model:

A random records partition into 75 percent of the points were used for model building, species prediction "training data" and 25 percent for model testing "testing data" (extrinsic and independent test data sets were used for the evaluation of the model's predictive performance). The calculation of the area under the curve (AUC) was performed for statistical validation of the model. AUC is used as an indicator of the model's accuracy (Phillips, 2016). The AUC is between 0 and 1. An AUC of 0.5 suggests a normal, and an AUC of 1 reveals a perfect model (Phillips *et al.,* 2004, Phillips *et al.,* 2006). The present study used The AUC classification system suggested by (Hosmer *et al.,* 2000). The AUC values are listed as: 0.5 – 0.6 = No discrimination; 0.6–0.7 = bad discrimination; 0.7 – 0.8 = acceptable discrimination; 0.8 - 0.9 = excellent discrimination; 0.9 –1.0 = outstanding discrimination (Hosmer et al., 2000). The internal jackknife test of the MaxEnt model was used to calculate the variables that most contribute to the development of the model. Additionally, Maxent provided the percentage contribution of each variable to the final model, according to the value of the increase in the model gain provided by each variable (Phillips *et al.*, 2006).

RESULTS

Insects that Induced Galls:

Asphondylia punica Marchal, 1897 (Diptera: Cecidomyiidae) larvae induce large galls on several parts of *Atriplex halimus* L. (Chenopodiaceae). The galls (fig. 2) grew on the stems, and, apical and axillary buds of *A. halimus*. Fusiform galls bear a number of protuberances, each containing a gall chamber. They are consist of several densely stunted leaves. The stem inside is stunted and swollen to a very hard. The fresh galls are green but become yellowish after the gall midges emergence and may still be attached to the plant until the next season. Two generations were recorded during a year. One was recorded from November to April and anther was recorded from May until October.

Factors Affecting the Distribution of The Insect Galls Induced on *A. halimus*:

1. Correlation Between the Number of Galls Per Plant, Plant Cover, And Altitude:

There was a significantly positive correlation between the number of galls per plant and the plant cover within the study locations ($r = 0.296$, $P < 0.05$). Meanwhile, there was no significant correlation between the number of galls per plant and the altitude within the study localities (Fig. 3).

2. Spatial Distribution of The Number of Galls Induced on *A. halimus* Among Different Localities:

The number of galls induced on A. Halimus showed a significant difference among various localities (Merghem, El-Tafaroa, Al Hawaria, Burg El-arab, El-Gharbaniat, El- Amria and Abd-Elkader) ($F (6, 50) = 1.187$ $P < 0.05$) (Fig. 4). El-Gharbaniat showed the greatest mean number of galls per plant 37.50; as compared to 32.50, 30.71, 29.50, 19.54, 15.00 and 4.37 at Al Hawaria, Merghem, El- Amria, El-Tafaroa, Burg El-Arab and El- Abd-Elkader, respectively.

Spatial Prediction Model of *A. halimus*:

1. The Predicted Distribution Range of *A. halimus* in Egypt:

The model of MaxEnt for *A. halimus* is shown in (Fig. 5). The predicted distribution habitat of *A. halimus* covers broad Mediterranean coastal areas, in addition to some areas in the Nile land region, the Red Sea coast, and South Sinai. Eighteen presence records used for training the model and five for testing. The AUC (Fig. 6) for the training points was 0. 947and for test points was 0.865, with a standard deviation of 0.033; The AUC exceeded 0.90, indicating outstanding discrimination for *A. halimus*. The minimum training presence among training points was 9.819. At this threshold, the fractional predicted area was 0.218 and the omission rate for test points was 0.000. The model classifies the test points correctly significantly more than a random model ($p < 0.001$).

2. Effect of Predictor Variables in The Representation of The Maxent Model for *A. halimus:*

According to the results of the variables contribution heuristic test (Fig. 7). *A. halimus* showed high sensitivity to Precipitation of Coldest Quarter (BIO19), Temperature Annual Range (P5-P6) (BIO7), Precipitation of Wettest Quarter (BIO16), Mean Diurnal Range (Mean of monthly (max temp - min temp) (BIO2), Precipitation of Wettest Month (BIO13), Precipitation of Warmest Quarter (BIO18), and Precipitation Seasonality (Coefficient of Variation) (BIO15), with contribution percentage equal to 24%, 21%, 17%, 16%, 9%, 8%, and 5%, respectively.

The MaxEnt model’s internal jackknife test of variable importance showed that Max Temperature of Warmest Month (BIO5) and Precipitation of Warmest Quarter (BIO18) were the most important predictors of *A. halimus* habitat distribution. These variables presented higher gains that included the most information as compared to the other variables.

Spatial Prediction Model of *A. punica*:

1. The Predicted Distribution Range of *A. punica* in Egypt:

The model of MaxEnt for *A. punica* is shown in (Fig. 8). The predicted distribution habitat of *A. punica* is mainly concentrated in some areas of the Nile delta north coast. Six presence records used for training, and two for testing. The AUC (Fig. 9) for the training points was 1.000 and for the test, points were 0.997, with a standard deviation of 0.001; The AUC was greater than 0.90, indicating outstanding discrimination for *A. punica*. The minimum training presence among training points was 48.778. At this threshold, the fractional predicted area was 0.001 and the omission rate for test points was 0.000. The model classifies the test points correctly significantly more than a random model ($p < 0.001$).

2. Effect of Predictor Variables In The Representation of the MaxEnt Model for *A. punic.*

According to the results of the variables contribution heuristic test (Fig. 10). *A. punica* showed high sensitivity to Precipitation of Wettest Quarter (BIO16), Temperature Seasonality (BIO4), Precipitation of Warmest Quarter (BIO18), Precipitation of Wettest Month (BIO13), Precipitation Seasonality (Coefficient of Variation) (BIO15), Min Temperature of Coldest Month (BIO18) and altitude, with contribution percentage equal to 41%, 30%, 12%, 8%, 4%, 3%, and 2%, respectively.

The internal jackknife test for MaxEnt showed that Wettest Quarter Precipitation (BIO16) is the most important predictor of *A. punica* habitat distribution. This predictor presented higher gains that included the most information as compared to the other variables.

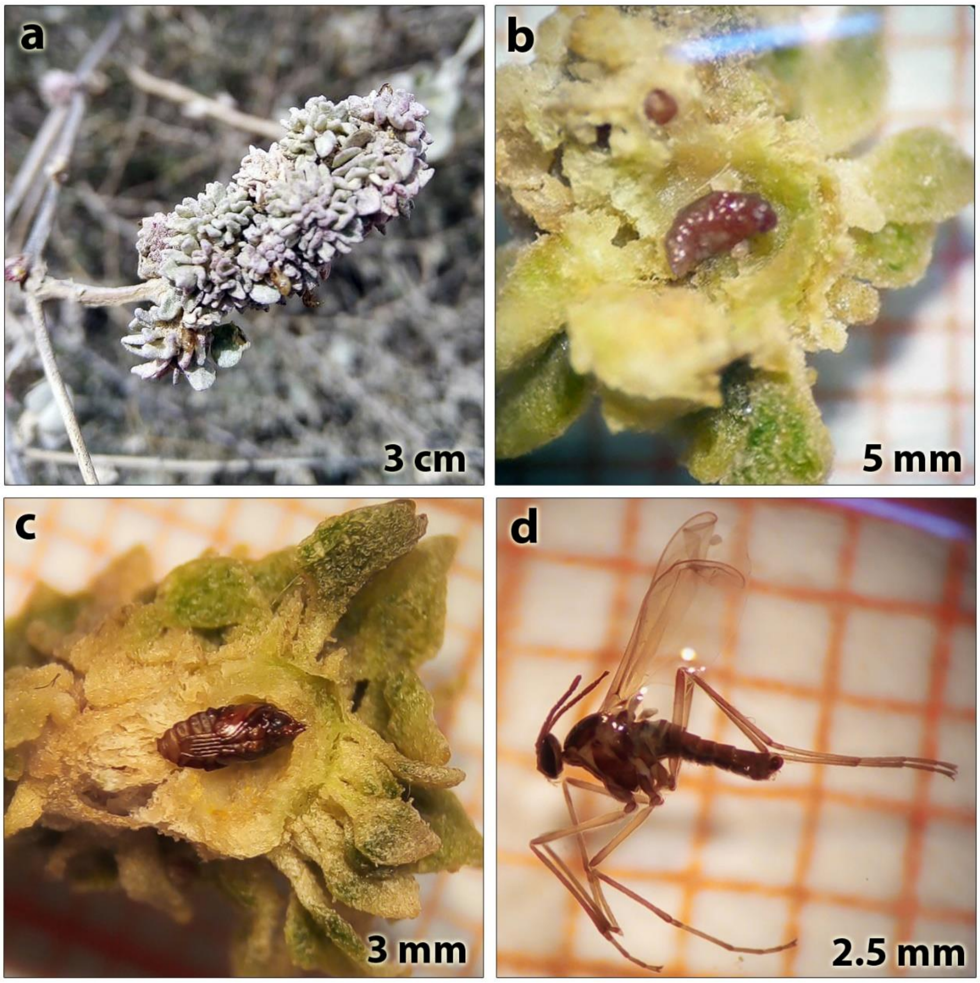

Fig. 2. The gall-midge *Asphondylia punica* (Diptera: Cecidomyiidae); (a) *Asphondylia punica* gall, (b) larvae (5 mm), (c) pupa (3 mm), and (d) adult (2.5 mm).

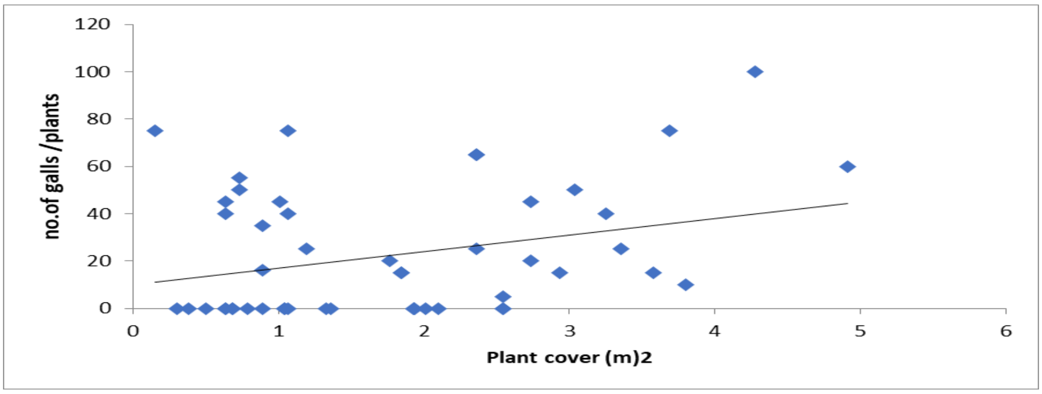

Fig.3. The relationship between the number of galls per plant and the plant cover within the study localities.

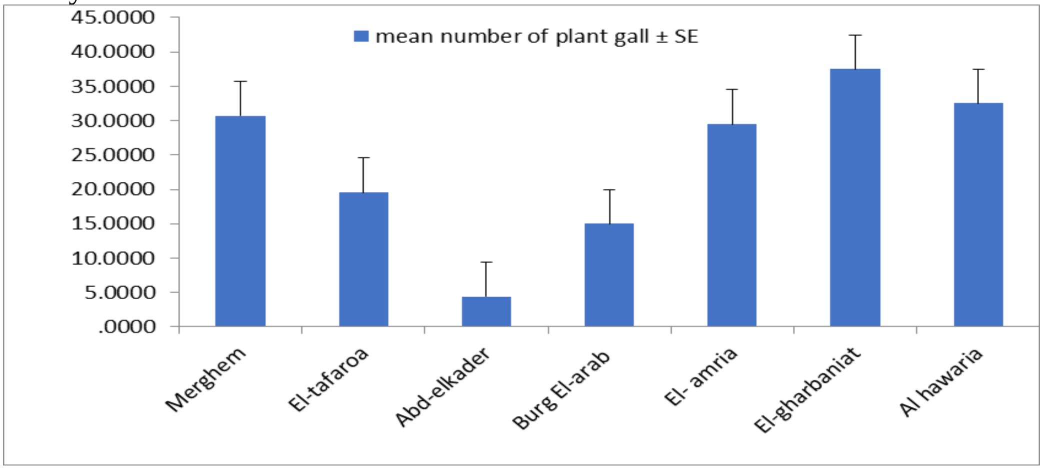

Fig. 4. The spatial pattern of gall distribution on the *A. halimus* among different study localities

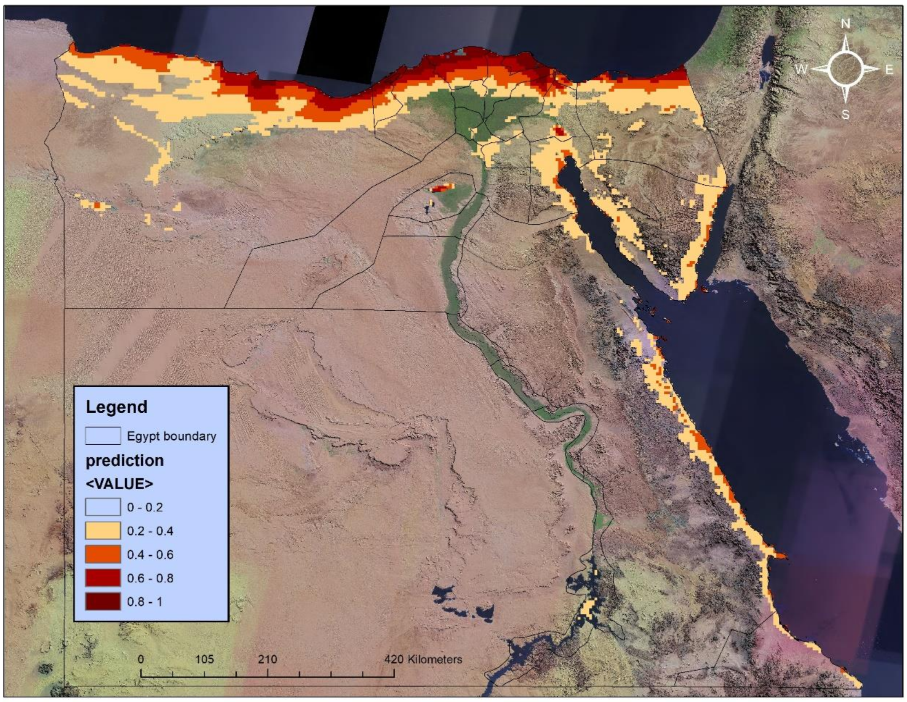

Fig. 5. The predicted distribution range of the *A. halimus* according to the MaxEnt model. (Map source: IESR, GIS unit & google map https://www.google.com.eg/maps/@27.4846068,31.3939550,6z).

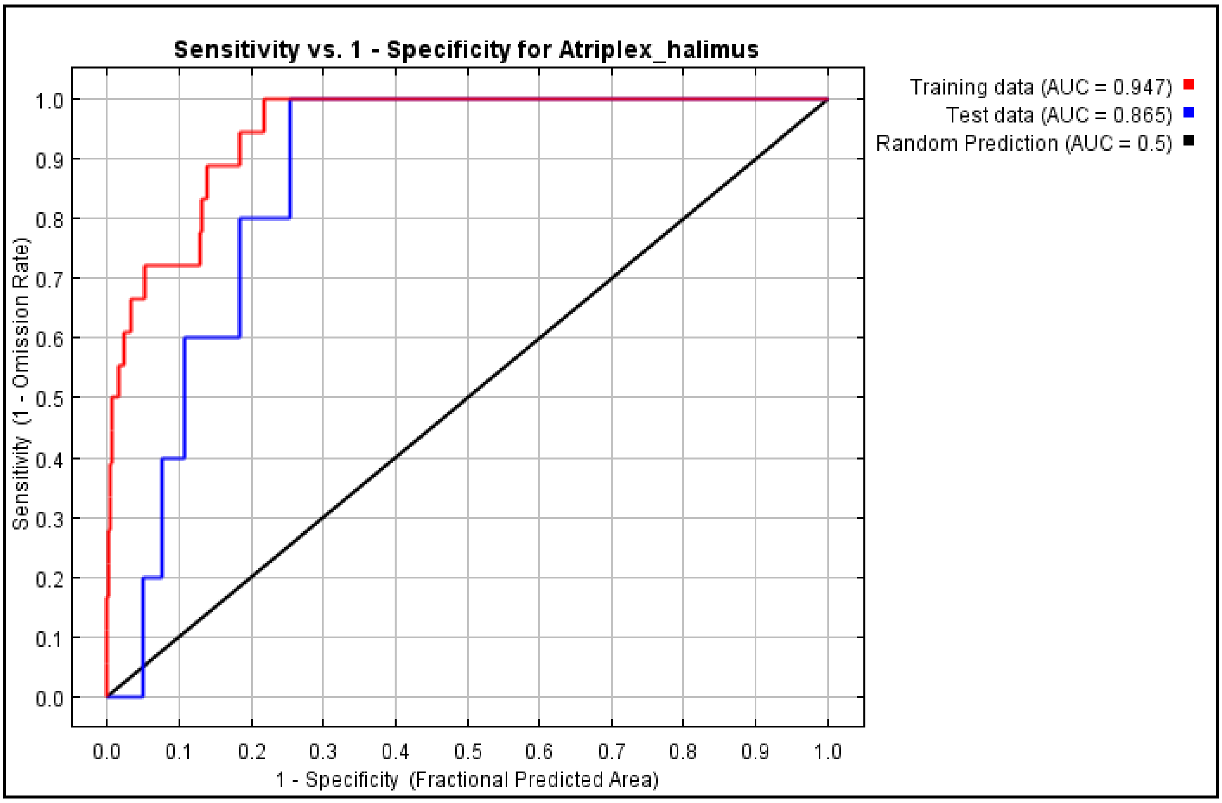

Fig.6. Training data (AUC = 0.947) and test data (AUC = 0.865) compared to random prediction (AUC = 0.5) in the receiver operating characteristic (ROC) curve for the representation of the MaxEnt model for *A. halimus.*

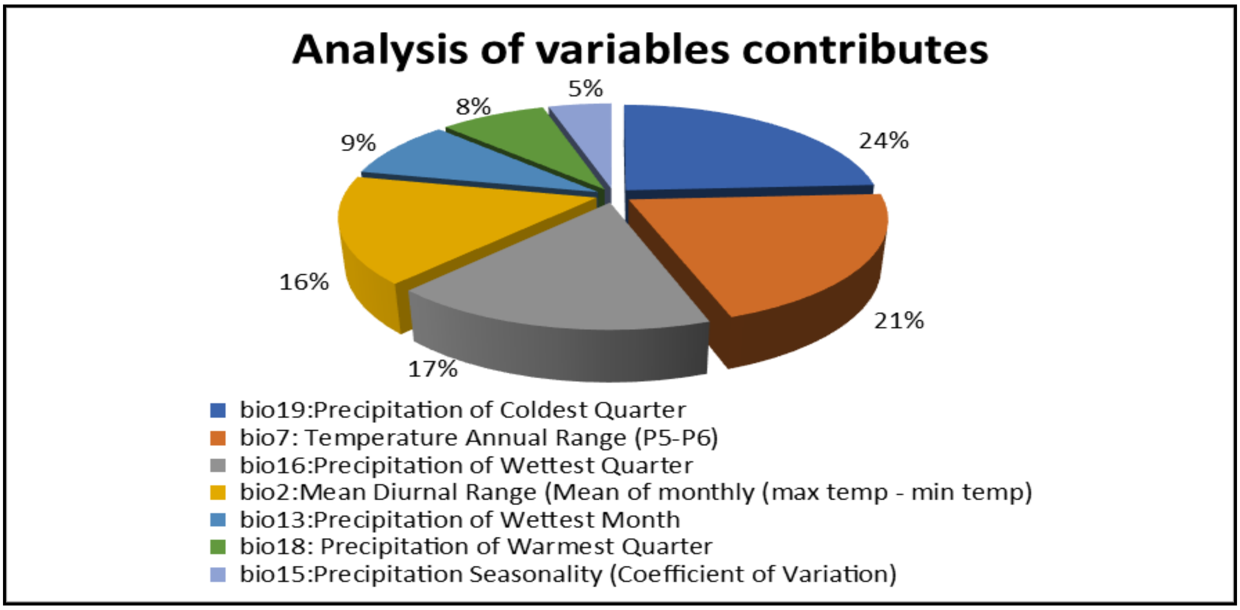

Fig.7. Analysis of variables contributes to the prediction distribution model of *A. halimus*

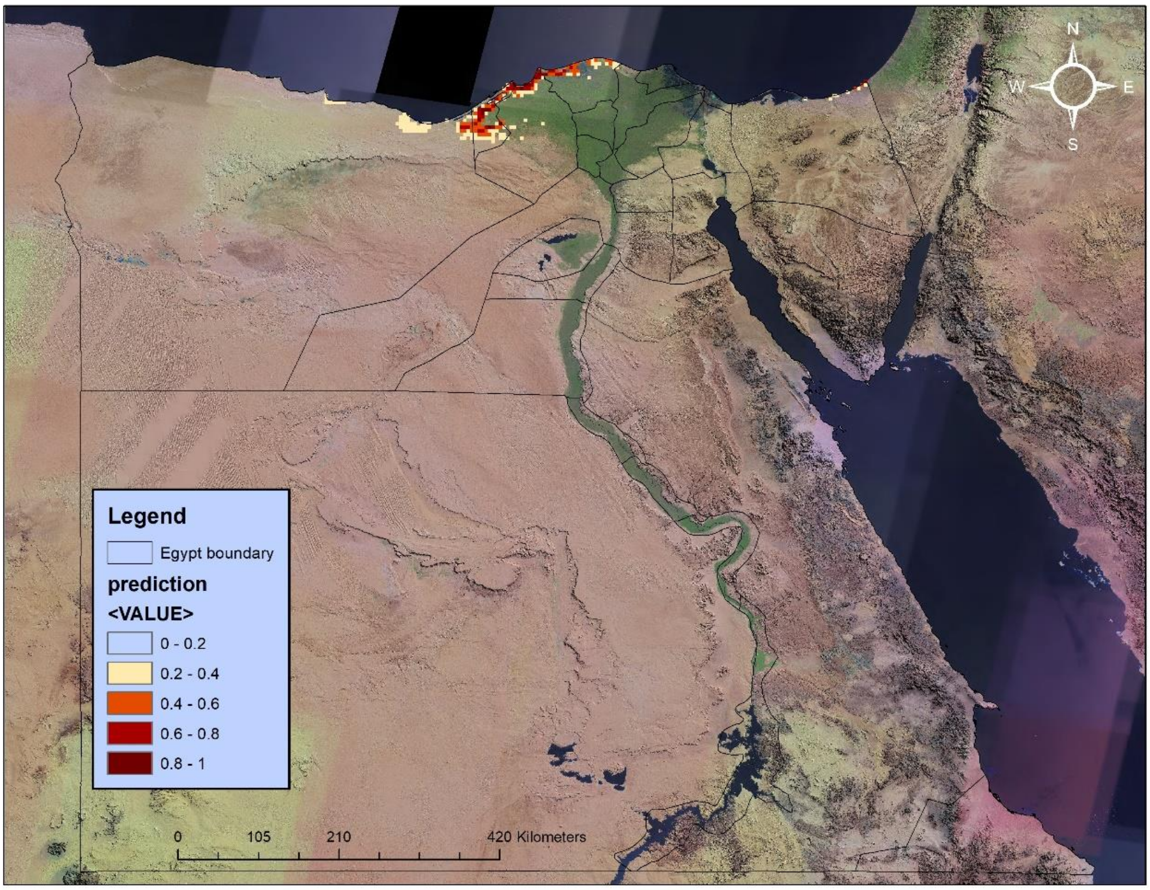

Fig. 8. The predicted distribution range of the *A. punica* according to the MaxEnt model. (Map source: IESR, GIS unit & google map https://www.google.com.eg/maps /@27.4846068,31.3939550,6z).

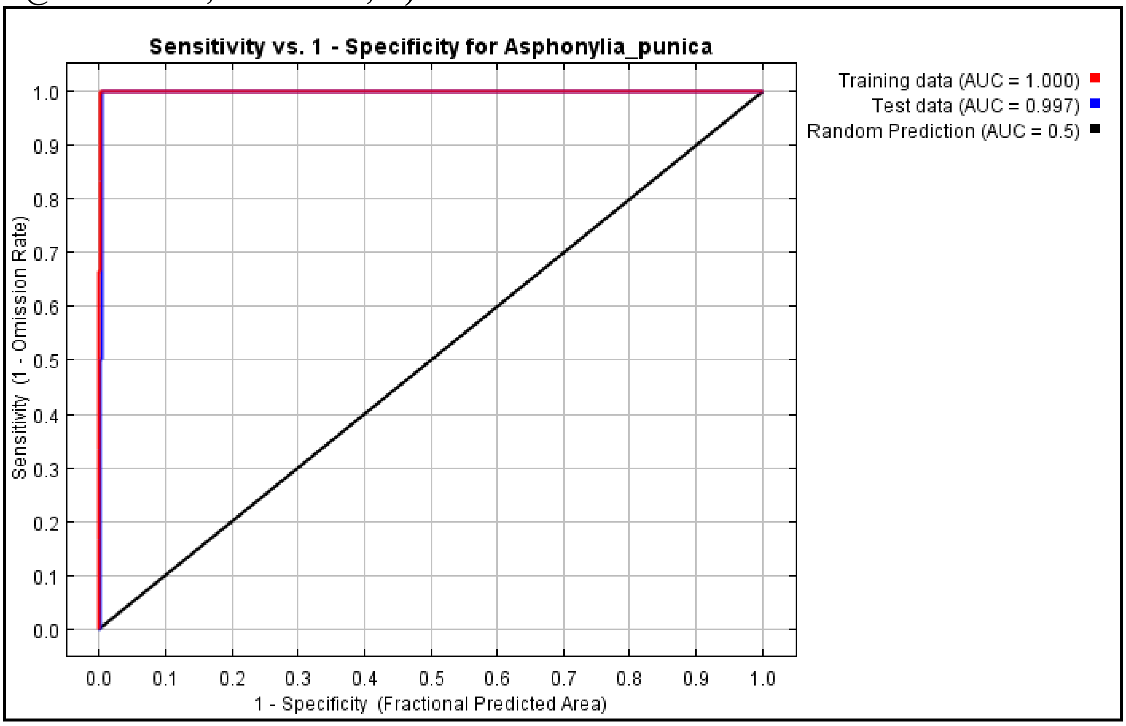

Fig.9. Training data (AUC = 1.000) and test data (AUC = 0.997) compared to random prediction (AUC = 0.5) in the receiver operating characteristic (ROC) curve for the representation of the MaxEnt model for *A. punica*.

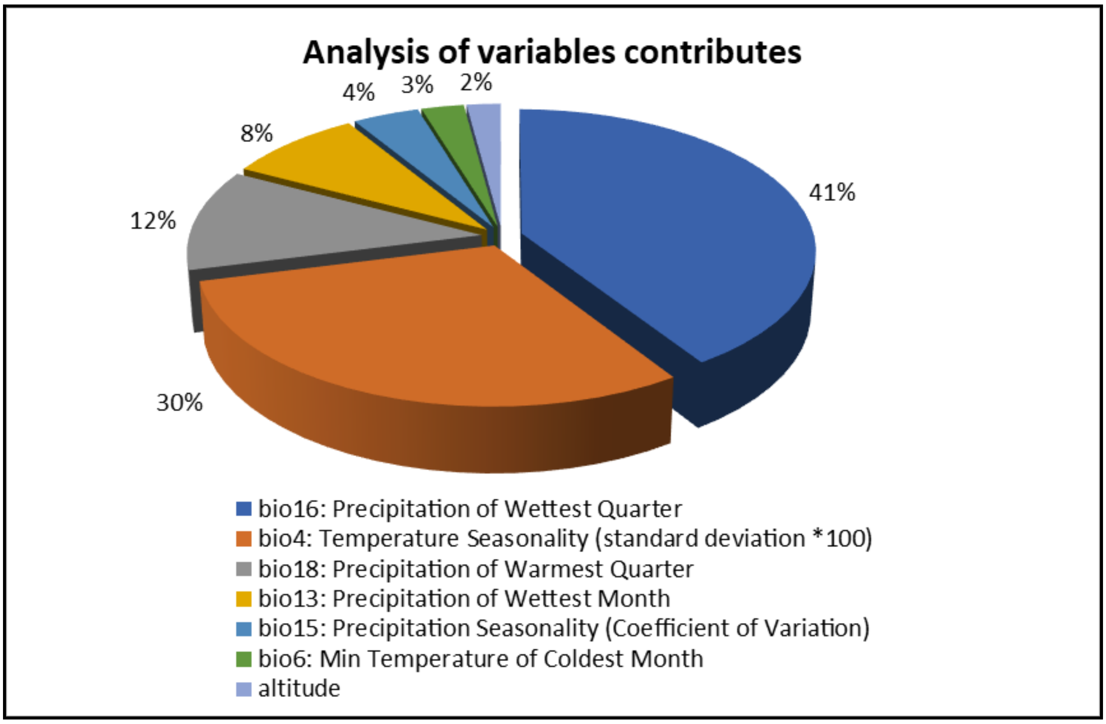

Fig.10. Analysis of variables contributes to the prediction distribution model of *A. punica.*

DISCUSSION

Gall-inducers usually prefer fast-growing and large plant organs, such as stems and leaves (Price, 1991). The current study showed that the stem of *A. halimus* is the most important part of the plant subjected to galls induction. It may be strongly attributed to enough area provided by the stem for gall induction (De Bruyn, 1994). Also, the gall-inducing insects prefer the more rewarding organs of the plant to form the gall (Whitham, 1978). Additionally, the present study suggests that the gall-inducing insects prefer the large plants more than the small ones which were evident from the positive correlation between the number of galls per plant and the plant cover. It may be attributed strongly to the availability of resources introduced by large plants, which supports the view of (Feeny, 1975). Furthermore, this agrees with the results of Daniela *et al.*, (2008) who showed that the number of galls is positively correlated to the biomass of the host plant and its branch number and also, with the view of (Fernandes, 1992) who recorded positive relationship between gall and plant richness for the vegetation of Indonesia. Also, the results agree with the first hypotheses of (Araújo, *et al.*, 2006) who reported that the increase of plant architecture leads to increases in species richness and abundance of gall-inducing insects. Additionally, the results agree with the view of Wright and Samways (1996, 1998) who showed that the richness of plant species could play a pivotal role in diversifying gall-forming species. But, the results did not agree with the view Fernandes and Price (1988) who showed that the diversity of gall-inducing insect species is independent of plant species abundance. More structurally complex plants support a greater diversity of herbivorous insects to provide more microhabitats, sites for ovipositing, and escape from natural enemies, making insects more appealing and seeming (Lázaro-González *et al.*, 2017).

A. punica showed high sensitivity to environmental factors such as Precipitation of Wettest Quarter (BIO16), Temperature Seasonality (BIO4), Precipitation of Warmest Quarter (BIO18), Precipitation of Wettest Month (BIO13), Precipitation Seasonality (Coefficient of Variation) (BIO15), Min Temperature of Coldest Month (BIO18) and altitude. This agrees with (Blanche, 2000; Butterill & Novotny, 2015; Da Costa *et al.*, 2011) they decided that environmental factors can influence the structure of gall-inducing insect communities.

The current study found that the habitat distribution model of *A. punica* and its host plant *A. halimus* in Egypt can be run by using a small number of occurrence records together with environmental predictor layers for the study area through the maximum entropy modeling technique (MaxEnt). So the present study agrees with the finding of (Hernandez *et al.,* 2006, Kamel *et al.,* 2012) who suggested that the Maxent technique worked better for species with very small occurrence records that have relatively wide geographic distributions.

Also, the present study showed that the predicted distribution range size for *A. punica* is less than the total predicted distribution range size for *A. halimus*. The predicted distribution habitat of *A. punica* is mainly concentrated in some areas close to the Mediterranean coast. This agrees with the view of (Doğanlar, M., & Elsayed, A. K., 2015) who reported that the distribution of *A. punica* is concentrated in Mediterranean regions. While, the predicted distribution habitat of *A. halimus* covers a wider region of the Mediterranean coast, in addition to some areas in the Nile land region, the Red Sea coast, and South Sinai. According to the present study, the MaxEnt model is an important technique for the prediction of species distribution and this agrees with the view of (Beck, 2013).

Conclusion:

The present study suggests that the gall inducers prefer the large plants more than the small ones which were evident from the positive correlation between the plant size and the number of galls per plant. Additionally, the current study showed that the predicted distribution range size for *A. punica* is less than the predicted distribution range size for *A. halimus*. The predicted distribution habitat of *A. punica* is mainly concentrated in the Nile's delta north coast. While, the predicted distribution habitat of *A. halimus* covers a wider region of the Mediterranean coastal land, in addition to some areas in the Nile land region, the Red Sea coast, and South Sinai.

Recommendations:

-Depend on the results and analysis of prediction; we put forward the following Suggestions:

- Studying more about plant galls induction in Egypt as a unique form of insect-plant interactions.
- We need to pay more attention to the suitable areas of the gall inducer *A. punica* and its host plant *A. halimus* in Egypt, which should be the important areas for protection.
- Collect the data from different spaced locations to make the model more accurate.

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ARABIC SUMMARY

دراسة العلاقة بين *أسفونلديا بونيكا وأتريبلكس هاليمس* والتنبؤ بتوزيعها الجغرافي المحتمل في مصر باستخدام تقنية الماكسنت.

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تمثل الأورام النباتيه والحشرات المسببة لها أحد أكثر التحديات التي تواجه علماء الحشرات بسبب تاريخ حياتهم الفريدة وبنية الصفراوات الحشرية المميزة. ترتبط*أسفونلديا بونيكا* (فصيلة السيسيدوميدي، رتبة ثنائيات الأجنحة) بأحد أهم النباتات الطبية*أتريبلكس هاليمس* حيث يستحث التورم المغزلي على جذع نبات *أتريبلكس هاليمس* ويكون عدة غرف. وقد تمت دراسة العلاقة بين حشرة *أسفونلديا بونيكا* والنبات المضيف *أتريبلكس هاليمس*. أشارت النتائج إلى وجود علاقة ارتباط معنوية بين عدد الأورام النباتيه والغطاء النباتي ولكن لا توجد علاقة ارتباطية بين عدد الأورام النباتيه لكل نبات والارتفاع. تمت دراسة التوزيعات المتوقعة لحشرة*أسفونلديا بونيكا* في مصر باستخدام تقنية الماكسنت. أوضحت النتائج أن التوزيع الإحتمالى لحشرة*أسفونلديا بونيكا* والنبات المضيف*أتريبلكس هاليمس* يتركز في مناطق ساحل البحر المتوسط.