EGYPTIAN ACADEMIC JOURNAL OF
BIOLOGICAL SCIENCES
ENTOMOLOGY

A

ISSN
1687-8809

WWW.EAJBS.EG.NET

Vol. 15 No. 4 (2022)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 15(4) pp.57-72 (2022)*
DOI: 10.21608/eajbsa.2022.267902

Egypt. Acad. J. Biolog. Sci., 15(4):57-72 (2022)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/

Mapping the Predicted Geographic Range of The Gall Former *Schizomyia botellus* (Diptera: Cecidomyiidae) under Influence of Climatic Factors in Arid Habitats.

Mohamed Kamel
Department of Environmental Basic Sciences, Faculty of graduate studies and environmental research, Ain shams University, Cairo, Egypt.
E-mail: Mohamed.kamel@iesr.asu.edu.eg

ARTICLE INFO
Article History
Received:19/8/2022
Accepted:17/10/2022
Available:25/10/2022

Keywords:
Galls, Prediction, Sinai, Interactions, and Bioclimatic variable.

ABSTRACT

In some localities of Sinai, the gall-midge *Schizomyia botellus* Dorchin & Freidberg, 2011 (Diptera: Cecidomyiidae) induce elongated galls on the axillary buds of *Deverra triradiata* Hochst. ex Boiss (Family: Apiaceae). The present work studies the relationship between S. *botellus* and *D. tortuosa*. Furthermore, the present study predicted the distribution of *S. botellus* in Sinai, Egypt by using Maxent modeling, in addition, to studying the influence of elevation and plant cover on its distribution.

The predominance of S. *botellus* occurred from January to April and adults emerge from the gall at the beginning of April after pupation. Endoparasitoids of the genus Inostemma (Platygastridae)occasionally attack the larvae of *S. botellus.* The distribution of *S. botellus* in Sinai is affected positively by plant cover and negatively by elevation. The predicted highly suitable habitat of *S. botellus* is mainly concentrated inside the boundary of the St. Katherine protectorate in south Sinai. The most bioclimatic factors that had an impact on *S. botellus*' predicted range was the maximum temperature of the warmest month, isothermality, and the amount of precipitation in the coldest quarter. Our findings can help ecologists define sampling regions and create conservation plans for this type of environmental interaction.

INTRODUCTION

Cells, tissues, or plant organs altered by hypertrophy and/or hyperplasia carried on by parasitic or pathogenic organisms are referred to as Cecidia or galls (Scott *et al.*, 1994). Plant galls are the outcome of the interaction between the gall inducer and the host plant (Raman, 1988). One of the major types of insect damage that results from contact with plants physically is galling, which affects fruits, flowers or flower buds, leaves, stems, and roots (Labandeira *et al.*, 2007).

The most illustrative manifestations of insect manipulation of plants are galls. The insect causes the plant to produce specialized nutritional and occasionally defensive resources that are beneficial to the insect at the expense of the plant's growth and reproduction by "reprogramming" the expression of the plant genome (Giron *et al.*, 2016). Insect gall induction results in decreased photosynthetic and transpiration rates, stomatal conductance, and water potential, stressing out the host plant (Florentine et al., 2001, Hazra *et al.*, 2022). Additionally, the gall-forming insects or their young receive feed, security,

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 15(4) pp.57-72 (2022)*
DOI: 10.21608/eajbsa.2022.267902

and shelter from the galls (Stone and Schönrogge, 2003, Ascendino and Maia, 2018). However, Insects that produce galls play a significant role in pollination (Borges, 2015). Several galls may contain tannins that are utilized for tanning and therapeutic purposes (Gerling *et al.,* 1976).

Gall-forming insects are excellent bioindicators of any changes in arid habitats and they reflect the level of an ecosystem's conservation and assess habitat restoration and quality (Julião *et al.*, 2005, Santana and Isaias, 2014, Kamel *et al.,* 2021).

All orders of herbivorous insects have gall-inducing insects (Fernandes *et al.*, 2011). Gall midges or Cecidomyiidae (Diptera: Nematocera) are prime examples of phytophagous insects that can manipulate the plant's defensive system. They redirect host nutrients for feeding and direct hormone transmission to change the shape of host cells, resulting in the creation of galls (Bentur *et al.*, 2016).

In comparison to mesic settings, xeric habitats have a wider variety of gall-forming insects (Fernandes and Price, 1988, Fernandes and Price, 1991, Santos-Silva *et al.*, 2022). Recently, numerous gall midges were observed producing various plant galls in arid habitats of Egypt (Kamel, 2012, Kamel *et al.*, 2012, Kamel, 2021). Sinai is a fascinating phytogeographic arid area due to its proximity to the Mediterranean, Irano-Turanian, Saharo-Arabic, and Sudanese regions (Zohary, 1973). As the arid region is usually marked by little precipitation and frequent droughts (Mabbutt, 1977). Thus, The most critical abiotic factors controlling the distribution of species are water availability, annual precipitation, and topography (Abd El-Ghani and Amer, 2003).

The genus *Schizomyia* belongs to the gall midges. It is distinguished by its global distribution (Frauenfeld, 1859, Elsayed *et al.*, 2018, Elsayed et al., 2019, Elsayed et al., 2020, Santos *et al.*, 2020). The only Schizomyia species known to pupate inside their galls are *Schizomyia botellus* and *S. buboniae.* Although *Schizomyia botellus* is bigger than *S. buboniae,* the two species' adults have remarkably similar morphologies overall (Dorchin and Freidberg, 2011). Galls of *Schizomyia botellus* Dorchin & Freidberg, 2011 (Diptera: Cecidomyiidae) were induced on *Deverra triradiata* (in Egypt and Israel) and on *Deverra scoparia* (in Tunisia) (Dorchin and Freidberg, 2011).

Deverra triradiata Hochst. ex Boiss (Family: Apiaceae) is a perennial chamaephyte shrub used to treat asthma, and intestinal cramps and against intestinal parasites (El-Seedi *et al.*, 2013, Farahat and Gärtner, 2021). It is utilized by Bedouins in Sinai and Palestine to control menstruation and treat haematuria and leukoderma (Halim *et al.*, 1989, Halim et al., 1995). Its extracts demonstrated antioxidant and anti-cancer properties (Elmosallamy *et al.*, 2021, Guetat *et al.*, 2022). The plant grows in stony wadis (Boulos, 2000). It is distributed in Egypt (Sinai), Palestine, and Arabia and extends to Iraq (Guetat, 2022).

The relationship between various biotic and abiotic factors and gall-forming insects is a topic of great interest. Several factors contribute to the differential distribution of gall-forming insects such as the major influence of natural enemies, plant resistance, host plant species richness, the density of host plants, and dynamics of plant meristems and super-host plants (Oliveira *et al.*, 2016). Additionally, the biodiversity of vulnerable habitats in arid regions has been significantly impacted by some factors, including both climate change and human impacts (Zhang and Ma, 2008).

Species distribution models (SDMs) are commonly employed at various scales to forecast the potential distributions of species or geographical distribution of habitat suitability (Javed *et al.*, 2017). Also, SDMs have utilized land management and conservation planning (Wilson *et al.*, 2005) and to predict the effects of climate change on ecosystems and species (Khanum *et al.*, 2013). Additionally, these models such as Maxent (a maximum entropy approach) have been used to estimate the impact of environmental and biotic factors on species distribution and abundance, and patterns of species richness even with low presence data (Phillips *et al.*, 2006, Hernandez *et al.*, 2006, Sreekumar *et al.*, 2016). some research was performed using a maximum entropy approach for forecasting the geographic distribution of various species in arid regions of Egypt (El Alqamy *et al.*, 2010, Ragab *et al.*, 2020a, Ragab *et al.*, 2020b, Kamel *et al.*, 2021)

Therefore, the main aim of this research was to map the geographic range of *S. botellus* in Sinai using the Maxent technique for determining the suitable areas for conservation. Furthermore, this research tried to determine the interaction of *Schizomyia botellus* with *Deverra triradiata* in some arid regions of Sinai and discover the impact of elevation and plant cover on galls induction.

MATERIALS AND METHODS

Study Area:

The current study was conducted in some arid regions of Sinai, Egypt. The chosen sampling sites for *S. botellus* galls were shown in (Fig. 1 & Table 1). The study sites were visited periodically for two years, once every two months.

Study plants

Deverra triradiata Hochst. ex Boiss (Family: Apiaceae) is a strongly aromatic robust perennial shrub (1.5 m) distributed in coastal arid regions; It produces (3–4 mm)long ovoid fruits that are densely covered with whitish hirsute; bracts and bracteoles are caducous; and mericarps are often curved (Boulos, 2000, Migahid, 1989).

Collection and Identification of Specimens:

Vegetation cover, besides the number of galls on different parts of the plant, was calculated according to (Qi *et al.*, 2019). Vegetation samples were identified according to (Boulos, 2000, and Migahid, 1989). Insect specimens are kept in vials with 75% alcohol and handled under a stereomicroscope (model M-C-9) using an analysing needle and a pair of small, sensitive forceps to avoid skewing the specimen. The immature stages of *S. botellus* inside the galls were taken from the study localities and grown in the laboratory until the adults emerge.

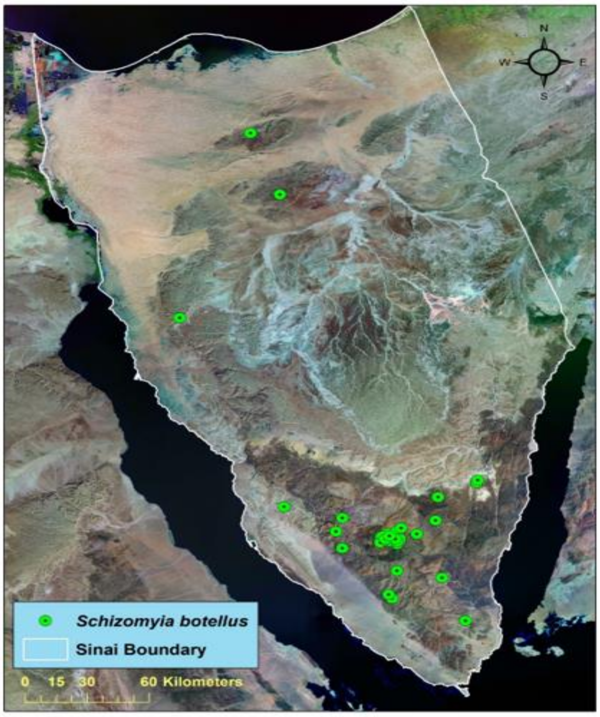

Fig. 1. The sampling localities for *S. botellus* galls in Sinai, Egypt. (Map source: FGSER, GIS unit).

Table 1: The sampling sites for *S. botellus* galls in Sinai, Egypt.

No.	Location	Coordinates	
		Latitude	Longitude
1	Abo Gefa	28.54743	33.93700
2	Abo Tweata	28.57050	33.89582
3	Abo Zatona	28.59995	33.97611
4	Albogeia	28.58963	33.92001
5	El-Gabal El-Molawan	28.57848	34.06310
6	El-Gabel El-Ahmer	28.53155	33.96141
7	Farsh El Losa	28.54821	33.96869
8	Farsh El-Homar	28.54325	33.96920
9	Farsh Mesela	28.57514	33.88812
10	Farsh Romana	28.54286	33.88080
11	Farsh Shoeab	28.54860	33.96582
12	Gabel Kathrine trail	28.53088	33.96402
13	Gabel Maghara	30.70242	33.37634
14	Gabel yalliq	30.37606	33.50265
15	Monastery Stairs	28.54540	33.97584
16	Ras Sedr	29.75889	32.96250
17	safsafa mountain	28.55136	33.96465
18	Sarfet Gabal Abas	28.54916	33.91632
19	Selebat	28.54449	33.93378
20	Shag Logar	28.60204	33.96952
21	Wadi Alwadii	28.75283	33.41966
22	wadi El Sheikh	28.61297	33.98836
23	Wadi El-Arbaein	28.54600	33.94915
24	Wadi El-Deer	28.55776	33.97799
25	Wadi El-Fereaa	28.61130	33.66720
26	Wadi El-Kid	28.34474	34.17169
27	Wadi El-mara	28.76462	34.18135
28	Wadi Faraa	28.54345	33.96382
29	Wadi Hebran	28.52258	33.69308
30	Wadi Isla	28.25069	33.91981
31	Wadi Kiri	28.82843	34.37665
32	Wadi Legibi	28.84143	34.38284
33	Wadi Mander	28.11625	34.27142
34	Wadi Moaged	28.27165	33.90434
35	Wadi Rahaba	28.39222	33.95333
36	Wadi Rem	28.68040	33.70219
37	Wadi Sakr	28.57609	33.89804
38	Wadi Sherage	28.55695	33.95686
39	Wadi Teanea	28.56024	33.90787
40	wadi Telah	28.57510	33.92820
41	Wadi Zaghraa	28.64388	34.16030
42	Zwatein	25.54474	33.91926

Data Analysis:

The collected samples were analyzed using the SPSS computer package (ver.20). The interaction between altitude, plant size, and the number of galls on each plant was evaluated using the Spearman correlation test. To compare the average number of galls per plant across various localities, a one-way ANOVA test was utilized.

Mapping and Climatic Data Selection:

The potentially suitable habitats of *S. botellus* in arid regions of Sinai were modeled using MaxEnt 3.4.1 (Phillips *et al.*, 2017). The maxent approach utilized occurrence points together with climatic variables layers for the study localities (Phillips, 2016). 19 standard bioclimatic variables with 2.5-minute geographic resolutions for the current situation were downloaded from the WorldClim database. (Fick and Hijmans, 2017). The suitable variables for modeling the distribution of *S. botellus* were chosen according to the standards of (Worthington *et al.,* 2016). The contribution of each climatic variable to the maxent model was calculated using the internal jackknife test. Also, to reduce the impacts of multi-collinearity and over-fitting, pairwise correlations were then calculated, and strongly correlated variables with a Pearson's r > 0.75 were eliminated from the model. (Wang et al., 2018). Therefore, only five climatic variables (including, Isothermality, Max Temperature of Warmest Month, Precipitation of Driest Month, Precipitation of Warmest Quarter, and Precipitation of Coldest Quarter) were employed according to the climatic variable contribution, and multicollinearity.

S. botellus's habitat distribution was categorized into four levels according to (Wei *et al.*, 2018): (0-5% unsuitable habitat), (6% -35% poorly suitable habitat), (36 -70%moderately suitable habitat), and (71 -100% highly suitable habitat).

Statistical Validation of The Model:

25% of the collection points were used for testing the model, while 75% of the collection points were used to develop the model and predict species. Model validation was performed by comparing the omission rates (i.e. percentage of test locations deviating from each algorithm's prediction) with calculations of the area under the curve (AUC) of the receiver operating characteristic to measure the accuracy of the model (Phillips, 2016). The AUC has a scale of 0 to 1. While an AUC of 1 implies an excellent model, an AUC of 0.5 shows a model that is no different from random (Phillips *et al.*, 2004, Phillips *et al.*, 2006).

RESULTS

1.*S. botellus* 's Gall Induction on *D. triradiate*:

The gall-midge *S. botellus* (Fig. 2) induced 371 galls on 93 individuals of *D. triradiata* within the study localities. According to the number and size of joints, the galls grow from axillary buds into elongated, jointed forms that range in length from 3 to 6 cm (Fig. 2). Galls are developed from January to April and adults emerge from the gall at the beginning of April after pupation. The light green gall is hollow and has more than 15 larvae inside. Larvae can be heavily attacked by internal hymenopteran parasitoids of the genus *Inostemma* (Platygastridae) (Fig. 3), each of which feeds on several larvae and may kill all the larvae inside the gall.

2. Factors affecting the distribution of *S. botellus* on *D. triradiata.*

There was a strong association between the amount of *S. botellus* galls per plant and the vegetative cover within the study sites ($r_s = 0.623$, $P < 0.01$) (Fig. 4). Meanwhile, there was a negative significant correlation between the number of *S. botellus* galls per plant and the Altitude within the study area ($r_s = -0.557$, $P < 0.01$) (Fig. 5). There was no significant difference in the number of *S. botellus* ' galls induced on *D. triradiata* among different localities ($F_{(41, 51)} = 0.538$ $P = 0.979$) (Fig. 6).

Fig. 2. The gall-midge *Schizomyia botellus* Dorchin & Freidberg, 2011 (Diptera: Cecidomyiidae); (a) The axillary buds galls (2-3 cm), (b) Ethanol-preserved larvae (3 mm), (c) pupa (2.5 mm), and (d) adult (3 mm).

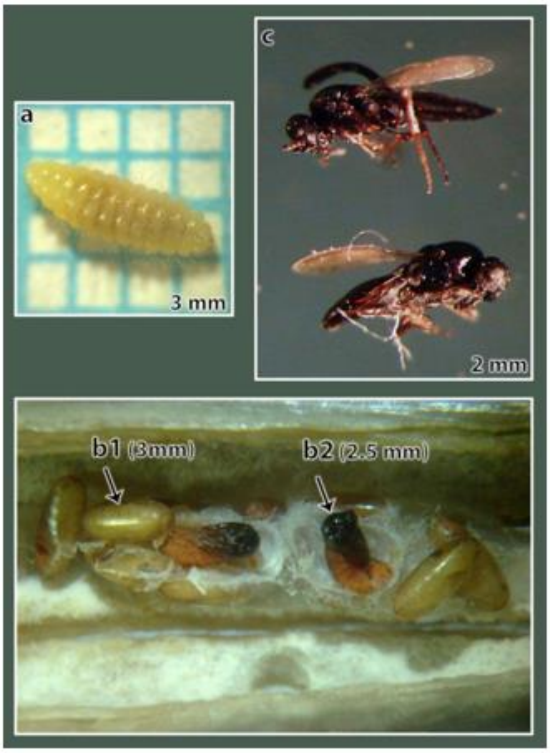

Fig. 3. The hymenopteran parasitoids *Inostemma* sp. (Platygastridae) (A) Ethanol-preserved larvae (3 mm), (b1) the endoparasite pupa (3 mm), (b2) the gall inducer pupa (2.5 mm) and (d) adult (2 mm).

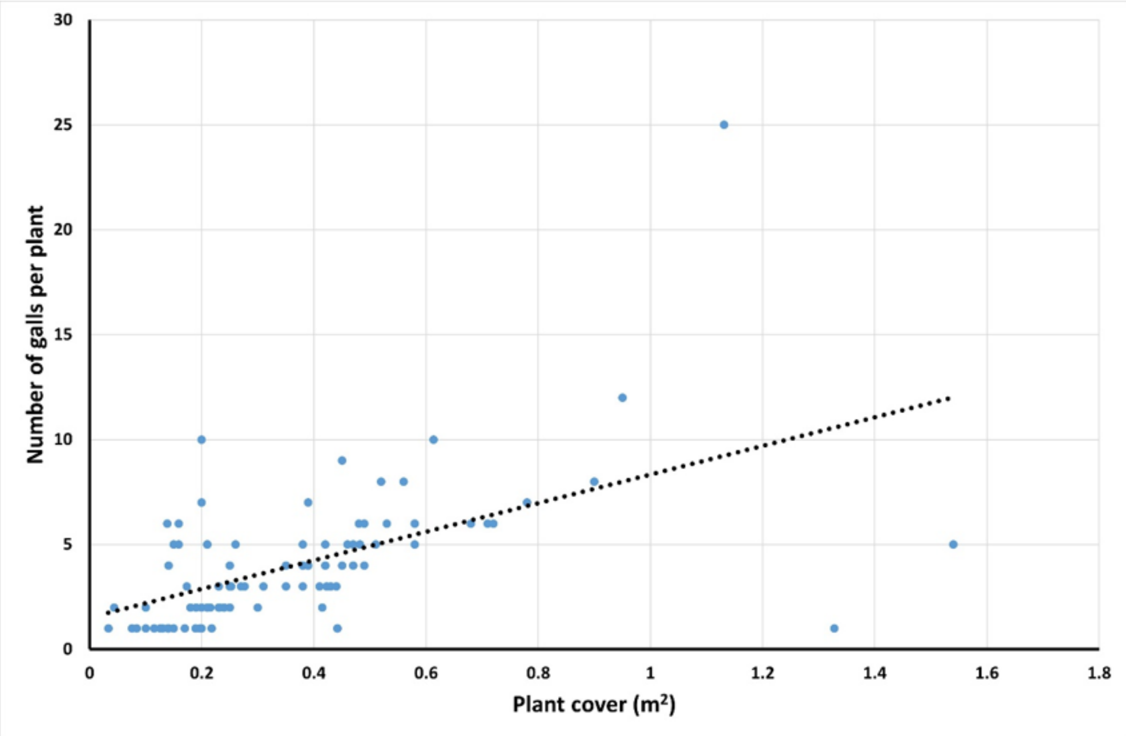

Fig. 4. The relationship between the number of *S. botellus* galls per plant and the plant cover within the study localities (rs = 0.623, P < 0.01).

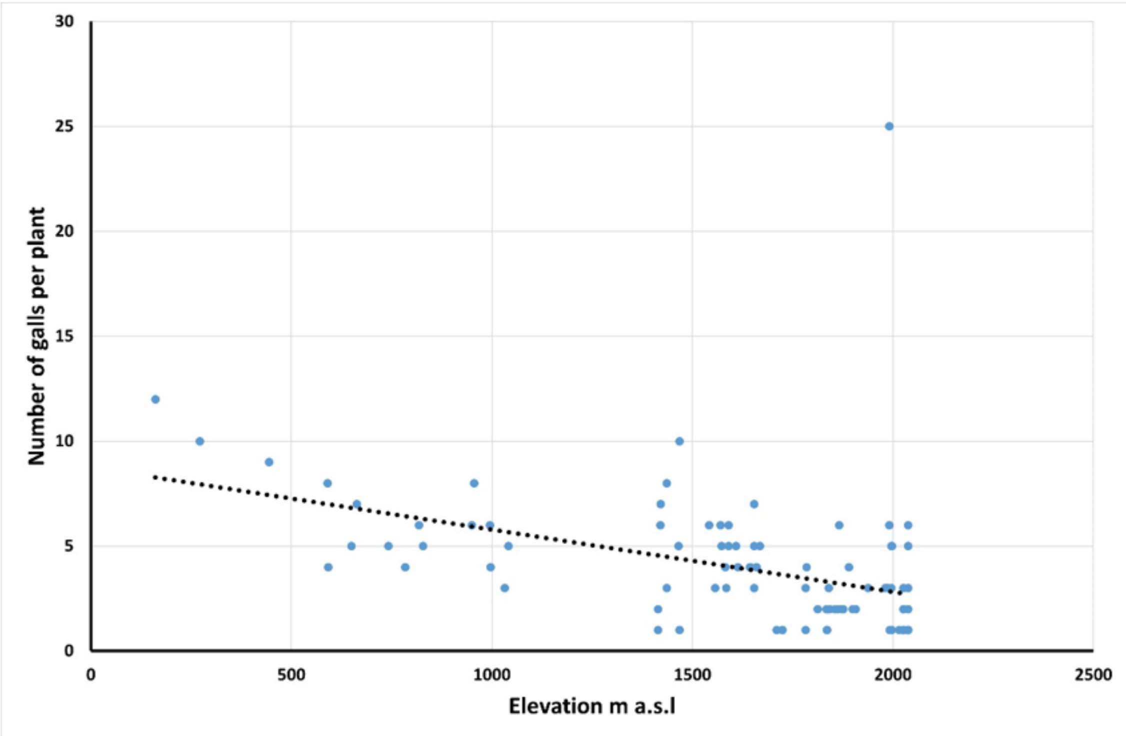

Fig. 5. The relationship between the number of *S. botellus* galls per plant and Altitude within the study area (rs = - 0.557, P < 0.01).

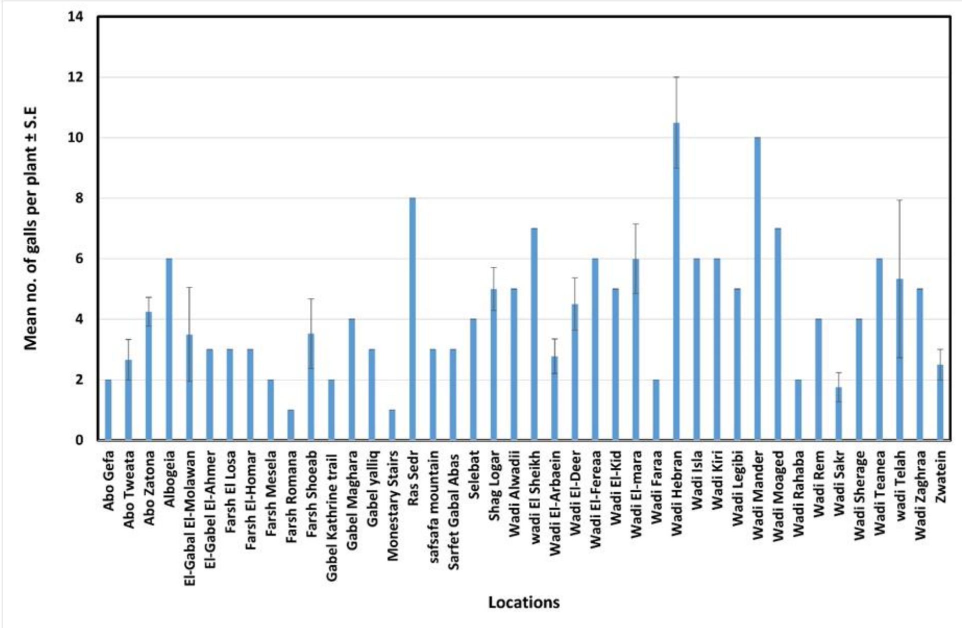

Fig. 6. The spatial pattern of gall distribution on the *D. triradiata* among different study localities (F (41, 51) =0.538 P = 0.979).

3 .The Ecological Niche Model for The Gall Midge *S. botellus* in Sinai, Egypt:

The predicted distribution model for *S. botellus* is shown in (**Fig. 7**). The predicted distribution habitat of *S. botellus* is mainly concentrated in the high-altitude region of south Sinai mainly inside the boundary of the St. Katherine protectorate. The AUC for the training points was 0.892 and for the test, points were 0.978, with a standard deviation of 0.012; The AUC value indicates high discrimination for *S. botellus*. The minimum training presence among training points was 1.2. While the fractional predicted region was 0.769 and the omission rate for test records was ZERO.

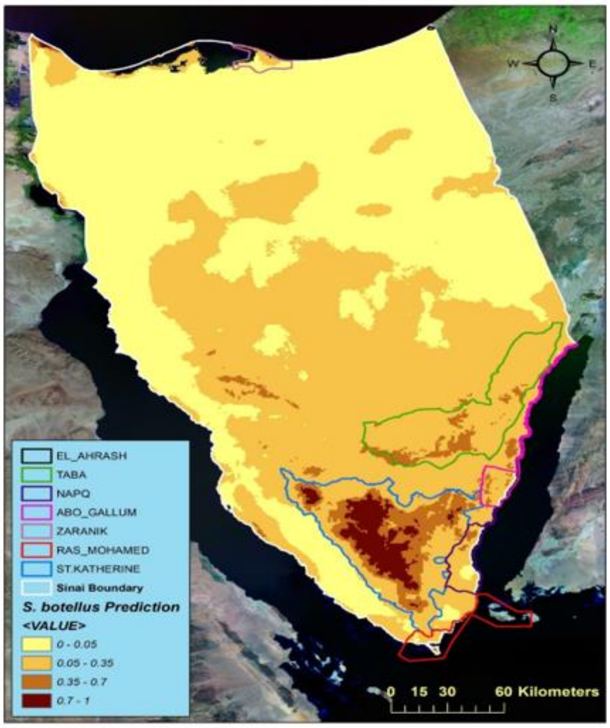

Fig.7. The predicted distribution range of the *S. botellus* in Sinai according to the MaxEnt model. (Map source: google Maps & FGSER, GIS unit).

1-The effect of bioclimatic variables on the ecological niche modeling of *S. botellus* in Sinai.

The climatic variable with the highest contribution value was Bio 14 (Precipitation of Driest Month). Considering the results of permutation importance, Bio 5 (Max Temperature of Warmest Month), Bio 3 (Isothermality), and Bio 19 (Precipitation of Coldest Quarter) were the most bioclimatic variables which have affected the predicted range of *S. botellus*.

The response curves of five climatic variables to *the S. botellus* predicted range is shown in (**Fig. 8**). The habitat suitability of *S. botellus* has a negative relationship with Bio 3, Bio 5, and Bio 19.

Table 3. The average contribution of the climatic factors used in *S. botellus* MaxEnt modeling.

Variable	Percent contribution	Permutation importance	Range
Bio 3	34.5	33	37.2 – 47.6
Bio 5	20	34.6	27 – 38 °C
Bio 14	37.8	0	0 – 1 mm.
Bio 18	1	0.8	0 - 7 mm.
Bio 19	6.7	31.6	1-150 mm.

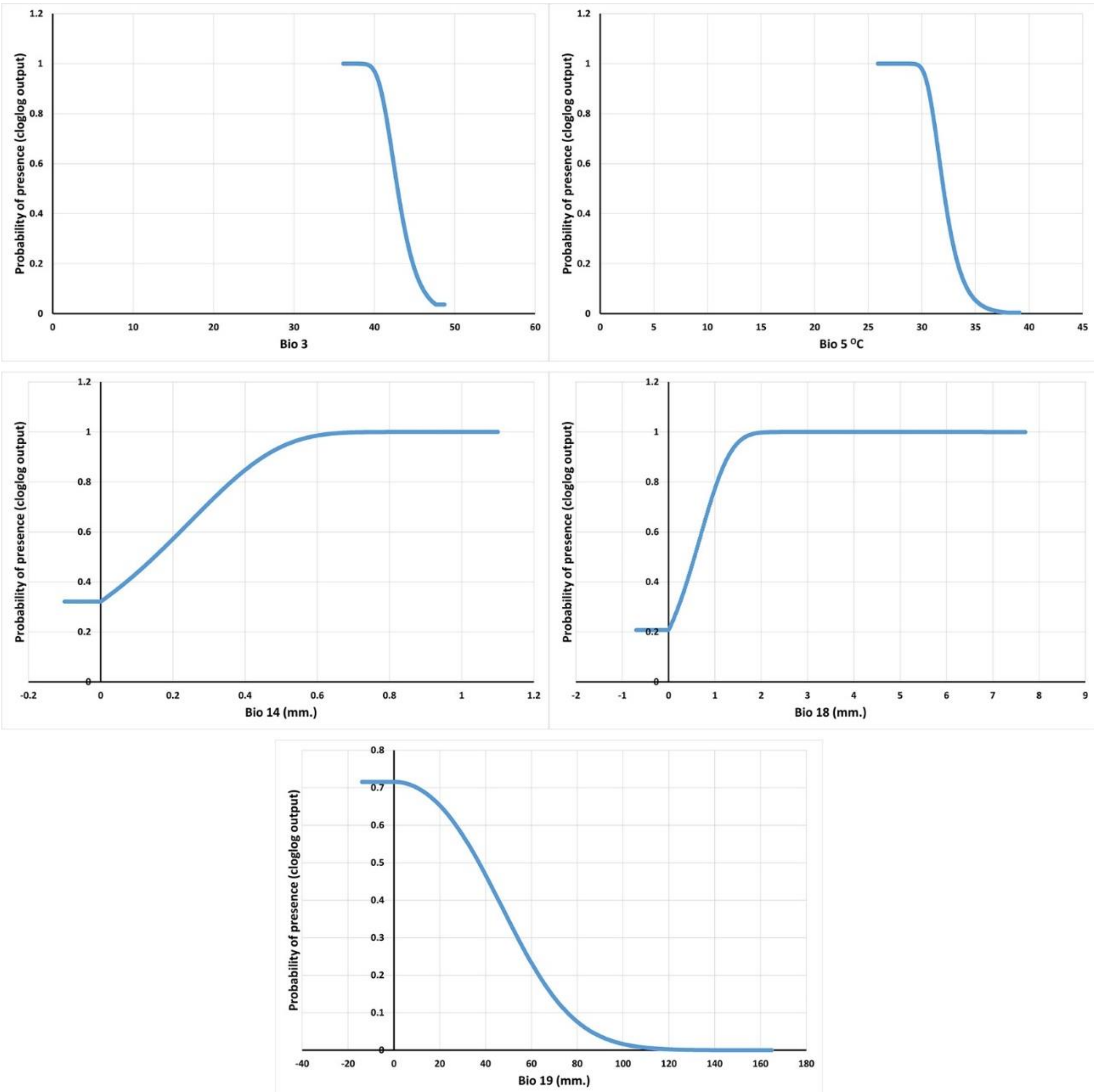

Fig. 8. Probability of *S. botellus* distribution under five climatic predictors in Sinai.

Areas of the potential present distribution for *S. botellus* are shown in (**Table 4).** Out of 60473.9 km^2 of the total area, *S. botellus's* potential unsuitable areas are 30450.9 km^2 (50.4 % of the total area). With a focus on moderately suitable habitat (0.36–0.70), habitat suitability for *S. botellus* is 2387.4 km^2 (3.9 % of the total area). while, in the Highly suitable habitat level (0.71-1.0), high habitat suitability for *S. botellus* is 1120.9 km^2 (1.8 % of the total area).

Table 4. The current predicted distribution range of *S. botellus* in Sinai (km^2).

Predicted class	*S. botellus* predicted distribution range	%
(0- 5%) Unsuitable habitat	30450.9	50.4 %
(6%-35%) Poorly suitable habitat	26514.6	43.8 %
(36%-70%) Moderately suitable habitat	2387.4	3.9 %
(71%-100%) Highly suitable habitat	1120.9	1.8 %
Total area	60473.9	100%

DISCUSSION

The diversity of plant species keeps the ecosystems stable and the diversity of gall-inducing insects (de Araújo *et al.*, 2013). Also, The plant's structural complexity can be the main factor for the distribution of gall-inducing insects (Fleck and Fonseca, 2007, de Araújo *et al.*, 2013). This study convincingly demonstrates that *S. botellus* prefers large vegetation more than small ones which was clear from the positive relationship between the plant cover and the number of *S. botellus* galls per plant. It might be firmly linked to the high resource availability by large plants, which supports the suggestions of (Price, 1991) who showed that more potent, large-size plants will be preferred by many types of herbivores. Therefore, the increase in vegetation size can be an indicator of the nutritional quality of galled plants (Cuevas-Reyes *et al.*, 2004).

Furthermore, The architecture of the galled plant may also contribute to an increase in the diversity of gall-making insects (de Araújo *et al.*, 2013). Also, Gall-making insects usually prefer particular parts of the host plant (Santos *et al.*, 2008), to maximize effectiveness and progeny survival. The present study showed that the axillary buds of *D. triradiata* are the most important part of the plant subjected to galls induction. Gall-making insects usually prefer fast-growing plant organs (Price, 1991).

The present work showed that other potential explanatory variables like altitude have an impact on the galls' induction on *D. triradiate*. This agrees with the findings of (Kamel *et al.*, 2012) who reported that the distribution of gall-making insects depends significantly on elevation in south Sinai. On contrary, this has not concurred with the view of (AraÚJo *et al.*, 2019) who suggested that altitude is not found to affect the diversity of gall-making insects in Brazil. The influence of temperature on the richness of the gall-making insects can be used to explain why the altitudinal gradient has a detrimental impact on gall inducers. (Blanche and Ludwig, 2001) concur that the temperature will rise as altitude decreases where species richness of the gall-making insects increases with decreasing elevation, which is accompanied by increasing temperature and aridity.

S. botellus' predicted distribution habitat is primarily concentrated in south Sinai's high-altitude region. This agrees with the findings of (Dorchin and Freidberg, 2011) who reported that the distribution of *S. botellus* is concentrated in ST. Katherine, south Sinai particularly in Wadi El Raha.

Gall-making insects are highly specialized to their host plants and react predictably to any environmental changes (Fernandes *et al.*, 2009). So, the current study showed that the gall midge *S. botellus* can be a vital tool for biodiversity conservation due to its highly specific relationship with its host plant D. triradiate. Additionally, the present study showed that the axillary buds of *D. triradiata* are facing gall induction by *S. botellus*. While the gall midge *Schizomyia buboniae* is inducing gall on the stem of *Deverra tortuosa* (Kamel *et al.,* 2021).

The present study showed that max temperature of the warmest month, isothermality, and precipitation of the coldest quarter were the most important predictors of *S. botellus* habitat distribution. This agrees with the findings of (Blanche and Ludwig, 2001, and Kamel *et al.*, 2021) who reported that gall-making insects show increases in performance at higher mean temperatures. Additionally, (Ragab *et al.,* 2020a) showed that precipitation in the coldest quarter was one of the most important predictors of *Baldratia salicorniae* habitat distribution.

Plant galls are notable for the association of a complex community of species from many insect groups, aside from the gall-making insects. These other species, which are present alongside the gall inducer inside the plant gall, may either be deadly parasites or benign inquilines. (Sanver and Hawkins, 2000). The current investigation showed that Hymenopteran parasitoids of the species *Inostemma* (Platygastridae), which are recorded inside the plant galls to profit from the contained nutrients, occasionally attack the *S. botellus* larvae. *Inostemma* sp. was endoparasitoid for the *S. buboniae* and *S. botellus* larvae that develop galls on *D. tortuosa* and *D. triradiata* in Israel, according to results by Dorchin and Freidberg, (2011).

Conclusions

The predicted *S. botellus* habitat is primarily located inside the St. Katherine protectorate's border in south Sinai. The current study demonstrated that other potential explanatory factors, such as altitude and the architecture of the galled plant, can affect how D. triradiate develops galls. Studying plant gall induction in Sinai as a particular type of insect-plant interaction is crucial, according to our analysis and prediction results. The appropriate habitats of *S. botellus* and its host plant *D. triradiata* in Sinai also require more study since they should be prioritized for protection.

List of Abbreviations

Alt	Altitude
AUC	the area under the curve.
Bio3	Isothermality (P2/P7) (* 100).
Bio5	Max Temperature of Warmest Month.
Bio14	Precipitation of Driest Month.
Bio18	Precipitation of Warmest Quarter.
Bio19	Precipitation of Coldest Quarter.
MaxEnt	the maximum entropy modeling technique.
P	Probability
ROC	the receiver operating characteristic.
rs	Spearman correlation coefficient.
Sig.	Significant.

Declarations:

Ethics approval and consent to participate: Not applicable.

Availability of data and material: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions: MK collected the data, analyzed, and interpreted the results of Mapping the geographic range of the gall former *Schizomyia botellus* (Diptera: Cecidomyiidae) under climatic factors in arid habitats. MK was a major contributor to writing the manuscript. the author read and approved the final manuscript.

REFERENCES

Abd El-Ghani, M. M. & Amer, W. M. 2003. Soil–vegetation relationships in a coastal desert plain of southern Sinai, Egypt. *Journal of Arid Environments,* 55**,** 607-628.

Araújo, W. S., Fernandes, G. W. & Santos, J. C. 2019. An overview of inventories of gall-inducing insects in Brazil: looking for patterns and identifying knowledge gaps. *Anais da Academia Brasileira de Ciências,* 91.

Ascendino, S. & Maia, V. C. 2018. Insects galls of Pantanal areas in the State of Mato Grosso do Sul, Brazil: characterization and occurrence *Anais da Academia Brasileira de Ciências,* 90**,** 1543-1564.

Bentur, J. S., Rawat, N., Divya, D., Sinha, D. K., Agarrwal, R., Atray, I. & Nair, S. 2016. Rice–gall midge interactions: battle for survival. *Journal of Insect Physiology,* 84**,** 40-49.

Blanche, K. R. & Ludwig, J. A. 2001. Species richness of gall-inducing insects and host plants along an altitudinal gradient in Big Bend National Park, Texas. *The American Midland Naturalist,* 145**,** 219-232.

Borges, R. M. 2015. How to be a fig wasp parasite on the fig–fig wasp mutualism. *Current Opinion in Insect Science,* 8**,** 34-40.

Boulos, L. 2000. *Flora of Egypt, Vol. 2. ,* Cairo, Egypt, Al hadara publishing.

Cuevas-Reyes, P., Quesada, M., Hanson, P., Dirzo, R. & Oyama, K. E. N. 2004. Diversity of gall-inducing insects in a Mexican tropical dry forest: the importance of plant species richness, life-forms, host plant age and plant density. *Journal of Ecology***,** 707-716.

De Araújo, W. S., Scareli-Santos, C., Guilherme, F. A. G. & Cuevas-Reyes, P. 2013. Comparing galling insect richness among Neotropical savannas: effects of plant richness, vegetation structure and super-host presence. *Biodiversity and Conservation,* 22**,** 1083-1094.

Dorchin, N. & Freidberg, A. 2011. The gall midges (Diptera: Cecidomyiidae) of Apiaceae in Israel. *Zootaxa* 3044**,** 28-48.

El-Seedi, H. R., Burman, R., Mansour, A., Turki, Z., Boulos, L., Gullbo, J. & Göransson, U. 2013. The traditional medical uses and cytotoxic activities of sixty-one Egyptian plants: discovery of an active cardiac glycoside from Urginea maritima. *Journal of Ethnopharmacology,* 145**,** 746-757.

El Alqamy, H., Ismael, A., Abdelhameed, A., Nagy, A., Hamada, A., Rashad, S. & Kamel, M. 2010. Predicting the status and distribution of the Nubian Ibex (Capra nubiana) in the high-altitude mountains of south Sinai (Egypt). *Galemys: Newsletter of the Spanish Society for the Preservation,* 22**,** 517-530.

Elmosallamy, A., Ibraheem, E., Sarhan, M. & Hussein, S. A. A. 2021. Chemical and Biological Activities of Deverra triradiata Hochst. ex .Boiss. Aerial parts from St. Catherine, Southern Sinai, Egypt. *Egyptian Journal of Chemistry,* 64**,** 1387-1394.

Elsayed, A. K., Lin, S.-F., Yang, M.-M. & Tokuda, M. 2020. The first report of the genus Schizomyia (Diptera: Cecidomyiidae) in Taiwan, with description of a new species forming stem galls on Maesa perlaria var. formosana (Primulaceae). *Journal of Asia-Pacific Entomology,* 23**,** 1083-1088.

Elsayed, A. K., Wheeler, G. S., Purcell, M., Dyer, K., Zhang, J. & Tokuda, M. 2019. A new Schizomyia species (Diptera: Cecidomyiidae) inducing flower bud galls on Chinese tallow tree Triadica sebifera in its native range. *Applied Entomology and Zoology,* 54**,** 429-436.

Elsayed, A. K., Yukawa, J. & Tokuda, M. 2018. A taxonomic revision and molecular phylogeny of the eastern Palearctic species of the genera Schizomyia Kieffer and Asteralobia Kovalev (Diptera, Cecidomyiidae, Asphondyliini), with descriptions of five new species of Schizomyia from Japan. *ZooKeys,* 808**,** 123.

Farahat, E. A. & Gärtner, H. 2021. Ring-forming plants in the Egyptian deserts. *Flora,* 279**,** 151812.

Fernandes, G. W., Carneiro, M. A. A. & Isaias, R. M. S. 2011. Gall-inducing insects: from anatomy to biodiversity. *Insect bioecology and nutrition for integrated pest management. Boca Raton, CRC Press. 75*0*p***,** 369-395.

Fernandes, G. W. & Price, P. W. 1988. Biogeographical gradients in galling species richness. *Oecologia,* 76**,** 161-167.

Fernandes, G. W. & Price, P. W. 1991. Comparison of tropical and temperate galling species richness: the roles of environmental harshness and plant nutrient status. *Plant-animal interactions: evolutionary ecology in tropical and temperate regions. Wiley, New York***,** 91-115.

Fernandes, S. P. C., Castelo-Branco, B. P., Albuquerque, F. A., Brito-Ramos, A. B., Ferreira, A. L. N., Braga, D. V. V. & Almeida-Cortez, J. S. 2009. Galhas entomógenas em um fragmento urbano de Mata Atlântica no centro de endemismo de Pernambuco. *Revista Brasileira de Biociências,* 7.

Fick, S. E. & Hijmans, R. J. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International journal of climatology,* 37**,** 4302-4315.

Fleck, T. & Fonseca, C. R. 2007. Hipóteses sobre a riqueza de insetos galhadores: uma revisão considerando os níveis intra-específico, interespecífico e de comunidade. *Neotropical Biology and Conservation,* 2**,** 36-45.

Florentine, S. K., Raman, A. & Dhileepan, K. 2001. Gall-inducing insects and biological control of Parthenium hysterophorus L.(Asteraceae). *Plant Protection Quarterly,* 16**,** 63-68.

Frauenfeld, G. 1859. Ueber exotische Pflanzenauswüchse, erzeugt von Insekten. *J Verhandlungen der kaiserlichköniglichen zoologisch-botanischen Gesellschaft in Wien,* 9**,** 319-332.

Gerling, D., Kugler, J. & Lupo, A. 1976. The galls of insects and mites that occur on Tamarix spp. *Israel and the Sinai. Bollettino del Laboratorio di Entomologia Agraria "Filippo Silvestri" di Portici,* 33**,** 53-79.

Giron, D., Huguet, E., Stone, G. N. & Body, M. 2016. Insect-induced effects on plants and possible effectors used by galling and leaf-mining insects to manipulate their host-plant. *Journal of Insect Physiology,* 84**,** 70-89.

Guetat, A. 2022. The Genus Deverra DC.(Syn. Pituranthos Viv.): A natural valuable source of bioactive phytochemicals: A review of traditional uses, phytochemistry and pharmacological properties. *Journal of Ethnopharmacology,* 284**,** 114447.

Guetat, A., Abdelwahab, A. T., Yahia, Y., Rhimi, W., Alzahrani, A. K., Boulila, A., Cafarchia, C. & Boussaid, M. 2022. Deverra triradiata Hochst. ex Boiss. from the Northern Region of Saudi Arabia: Essential Oil Profiling, Plant Extracts and Biological Activities. *Plants,* 11**,** 1543.

Halim, A. F., Lahloub, M. F., Saad, H. E. & Ahmed, A. F. 1989. Coumarins of Pituranthos triradiatus Growing in Egypt. *Planta Medica,* 55**,** 609-609.

Halim, A. F., Saad, H. E., Lahloub, M. F. & Ahmed, A. F. 1995. Pituranthoside from Pituranthos triradiatus. *Phytochemistry,* 40**,** 927-929.

Hazra, M., Hazra, T., Spicer, R. A., Sarkar, S. K., Spicer, T. E. V., Bera, S. & Khan, M. A. 2022. Galling: the prevalent form of insect folivory in the latest Neogene monsoon-influenced tropical forests of the Chotanagpur Plateau, eastern India. *Palaeoworld,* 31**,** 550-564.

Hernandez, P. A., Graham, C. H., Master, L. L. & Albert, D. L. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. *Ecography* 29**,** 773-785.

Javed, S. M., Raj, M. & Kumar, S. 2017. Predicting Potential Habitat Suitability for an Endemic Gecko Calodactylodes aureus and its Conservation Implications in India. *Tropical Ecology,* 58.

Julião, G. R., Fernandes, G. W., Negreiros, D., Bedê, L. & Araújo, R. C. 2005. Insetos galhadores associados a duas espécies de plantas invasoras de áreas urbanas e peri-urbanas *J Revista Brasileira de Entomologia,* 49**,** 97-10.6

Kamel, M. 2012. *Plant galls of Sinai, Egypt. Plant galls induction in St. Katherine protectorate.* , KG Heinrich-Böcking-Straße, Germany, Lambert Academic Publishing GmbH & Co. .

Kamel, M. 2021. Hiking trails effects on the diversity of gall-inducing insects in high altitude ecosystem, St. Katherine Protectorate, Egypt. *Zoology in the Middle East,* 67**,** 48-56.

Kamel, M., Bream, A. S., Moursy, M. M. & Ragab, S. H. 2021. Predicting the geographic distribution habitats of Schizomyia buboniae (Diptera: Cecidomyiidae) and its host plant Deverra tortuosa (Apiaceae) in Egypt by using MaxEnt modeling. *The Journal of Basic and Applied Zoology,* 82**,** 1-13.

Kamel, M., Semida, F. & Abdel-Dayem, M. 2012. *Galls inducing insects in Sinai Ecosystem, Egypt. Gall inducing insects and their host plants in St. Katherine Protectorate,* KG Heinrich-Böcking-Straße, Germany, Lambert Academic Publishing GmbH & Co. .

Khanum, R., Mumtaz, A. S. & Kumar, S. 2013. Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modeling. *Acta Oecologica,* 49**,** 23-31.

Labandeira, C. C., Wilf, P., Johnson, K. R. & Marsh, F. 2007. Guide to insect (and other) damage types on compressed plant fossils. *Smithsonian Institution, National Museum of Natural History, Department of Paleobiology, Washington, DC*.

Mabbutt, J. A. 1977. Desert landforms: An introduction to systematic geomorphology. *Cambridge, Ma: MIT Press,* 86**,** 340.

Migahid, A. M. 1989. *Flora of Saudi Arabia, volume 2,* Riyadh, Saudi Arabia, king Saud university libraries.

Oliveira, D. C., Isaias, R. M. S., Fernandes, G. W., Ferreira, B. G., Carneiro, R. G. S. & Fuzaro, L. 2016. Manipulation of host plant cells and tissues by gall-inducing insects and adaptive strategies used by different feeding guilds. *Journal of Insect Physiology,* 84**,** 103-113.

Phillips, S. 2016. A brief tutorial on Maxent, versions: 3.3.1. . *Lessons in Conservation,* 3**,** 108-135.

Phillips, S. J., Anderson, R. P., Dudík, M., Schapire, R. E. & Blair, M. E. 2017. Opening the black box: an open-source release of Maxent. *Ecography,* 40**,** 887-893.

Phillips, S. J., Anderson, R. P. & Schapire, R. E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological modelling,* 190**,** 231-259.

Phillips, S. J., Dudík, M. & Schapire, R. E.2004. A maximum entropy approach to species distribution modeling. Proceedings of the twenty-first international conference on Machine learning, 83.

Price, P. W. 1991. The plant vigor hypothesis and herbivore attack. *Oikos***,** 244-251.

Qi, Y., Wei, W., Chen, C. & Chen, L .2019 .Plant root-shoot biomass allocation over diverse biomes: A global synthesis. *Global Ecology and Conservation,* 18**,** e00606.

Ragab, S. H., Kamel, M., Bream, A. S. & Moursy, M. M. 2020a. Baldratia salicorniae–Salicornia fruticosa Interaction and Modeling of Their Habitat in Egypt By Using Maxent Technique. *Egyptian Academic Journal of Biological Sciences, E. Medical Entomology & Parasitology,* 12**,** 27-41.

Ragab, S. H., Kamel, M., Bream, A. S. & Moursy, M. M. 2020b. Studying the Interaction Between Asphondylia punica and Its Host Plant, Atriplex halimus, and Predicting Their Potential Geographic Distribution in Egypt by Using Maxent Technique. *Egyptian Academic Journal of Biological Sciences. A, Entomology,* 13**,** 283-298.

Raman, A. 1988. Dynamics of cecidogenous insect–host plant interactions. *Dynamics of Insect—Plant Interactions. Oxford & IBH Publishing Co., New Delhi***,** 201-212.

Santana, A. P. & Isaias, R. M. D. S. 2014. Galling insects are bioindicators of environmental quality in a Conservation Unit *J Acta Botanica Brasilica,* 28**,** 594-608.

Santos-Silva, J., Dos Santos, G. A. B. & Santos, J. C. 2022. Soils and seasonality influence the richness of gall-inducing insects and their host plants in a tropical dry forest. *Journal of Arid Environments,* 196**,** 104651.

Santos, D. S. D. S. D., Cid Maia, V. & Calado, D. 2020. Insect galls on Bauhinia cupulata (Fabaceae): morphotypes characterization and description of a new species of Schizomyia (Cecidomyiidae, Diptera). *Revista Brasileira de Entomologia,* 63**,** 356-362.

Santos, J. C., Silveira, F. A. O. & Fernandes, G. W. 2008. Long term oviposition preference and larval performance of Schizomyia macrocapillata (Diptera: Cecidomyiidae) on larger shoots of its host plant Bauhinia brevipes (Fabaceae). *Evolutionary Ecology* , .137-123 ,22

Sanver, D. & Hawkins, B. A. 2000. Galls as habitats: the inquiline communities of insect galls. *Basic and Applied Ecology,* 1**,** 3-11.

Scott, A. C., Stephenson, J., Collinson, M. E. & Williams, M. A. J. 1994. The fossil record of leaves with galls. *Systematics Association Special Volume,* 49**,** 447-447.

Sreekumar, V. B., Sakthivel, R. S. & Sreejith, K. A. 2016. Distribution mapping and conservation of Rhopaloblaste augusta (Kurz) HE Moore in Nicobar Islands, India. *Tropical Ecology,* 57**,** 271-277.

Stone, G. N. & Schönrogge, K. 2003. The adaptive significance of insect gall morphology. *Trends in Ecology & Evolution,* 18**,** 512-522.

Wang, R., Li, Q., He, S., Liu, Y., Wang, M. & Jiang, G. 2018. Modeling and mapping the current and future distribution of Pseudomonas syringae pv. actinidiae under climate change in China. *PloS one,* 13**,** e0192153.

Wei, B., Wang, R., Hou, K., Wang, X. & Wu, W. 2018. Predicting the current and future cultivation regions of Carthamus tinctorius L. using MaxEnt model under climate change in China. *Global Ecology and Conservation,* 16**,** e00477.

Wilson, K. A., Westphal, M. I., Possingham, H. P. & Elith, J. 2005. Sensitivity of conservation planning to different approaches to using predicted species distribution data. *Biological Conservation,* 122**,** 99-112.

Worthington, T. A., Zhang, T., Logue, D. R., Mittelstet, A. R. & Brewer, S. K. 2016. Landscape and flow metrics affecting the distribution of a federally-threatened fish: Improving management, model fit, and model transferability. *Ecological Modelling*, 342**,** 1-18.

Zhang, Y.-B. & Ma, K.-P. 2008. Geographic distribution patterns and status assessment of threatened plants in China. *Biodiversity and conservation*, 17**,** 1783-1798.

Zohary, M. 1973. *Geobotanical foundations of the Middle East*, Fischer.

ARABIC SUMMARY

رسم خرائط التوزيع الجغرافي المتوقع لمسبب الأورام النباتية *سكيزوميا بوتيليس* (فصيلة السيسيدوميدي- رتبة ثنائيات الأجنحة) في المناطق القاحلة تحت تأثير العوامل المناخية.

محمـد كامل

قسم العلوم الأساسية البيئية – كلية الدراسات العليا والبحوث البيئية – جامعة عين شمس- مصر.

تحدث حشرة *سكيزوميا بوتيليس* (فصيلة السيسيدوميدي- رتبة ثنائيات الأجنحة) أورام نباتية ذات شكل طولي على البراعم الإبطية لنبات *ديفيرا ترايرادياتا* (الفَصِيلَة الخَيْمِيَّة) ببعض المناطق بشبه جزيرة سيناء. يدرس العمل الحالي العلاقة بين حشرة *سكيزوميا بوتيليس* ونبات *ديفيرا ترايرادياتا*. علاوة على ذلك، توقعت الدراسة الحالية توزيع حشرة سكيزوميا بوتيليس في سيناء بمصر باستخدام تقنية الماكسنت، بالإضافة إلى دراسة تأثير الارتفاع والغطاء النباتي على توزيعها.

تحدث الإصابة بالأورام النباتية بواسطة حشرة *سكيزوميا بوتيليس* بدءاً من شهر يناير وحتى شهر أبريل حيث يخرج الطور البالغ من الورم النباتي في بداية شهر أبريل بعد انتهاء مرحلة التشرنق داخل الورم النباتي. كما وجد ان الطفيليات الداخلية من جنس *إنوستيما* (فصيلة بلاتيجاستريدى- رتبة غشائيات الأجنحة) تهاجم يرقات حشرة *سكيزوميا بوتيليس* دخل الورم النباتي. يتأثر انتشار حشرة *سكيزوميا بوتيليس* في سيناء ايجابيا بالغطاء النباتي وسلبا بالارتفاع.

تتركز الموطن المتوقعة ذات الاحتمالية العالية لحشرة *سكيزوميا بوتيليس* بشكل أساسي داخل حدود محمية سانت كاترين في جنوب سيناء. وكانت أكثر العوامل المناخية الحيوية التي كان لها تأثير على النطاق المتوقع لحشرة *سكيزوميا بوتيليس* هي درجة الحرارة القصوى للشهور الأكثر دفئًا، ومعامل التساوي الحراري، وكمية هطول الأمطار في الربع الأكثر برودة. كما يمكن أن تساعد النتائج التي توصلنا إليها علماء البيئة في تحديد مناطق أخذ العينات ووضع خطط حماية لهذا النوع من التفاعل البيئي.