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Predicting the Geographical Distribution of The Leaf-Gall Thrips, *Gynaikothrips ficorum* (Marchal) and Their Interaction with Host Plants in Egypt

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ABSTRACT

Leaf-gall thrips, *Gynaikothrips ficorum* is an invasive pest that causes significant damage to some crops in Egypt. Understanding the geographical distribution of this pest and its interaction with host plants is crucial for effective management strategies. During the current study, ecological niche modeling was used to predict the future distribution of *G. ficorum* in Egypt based on environmental variables. We also investigated the interaction between *G. ficorum* and its host plant by analyzing the infestation rate and damage severity on different fig cultivars by using MaxEnt technique. *G. ficorum* has a high potential for spread throughout most of Egypt, with the ultimate suitability in the Nile Delta region. Additionally, we found one species of fig plant cultivars namely, *Ficus microcarpa* L. f. was more susceptible to infestation and damage by *G. ficorum*, highlighting the importance of selecting resistant cultivars for sustainable pest management. The results revealed that the number of galls per plant was positively correlated with plant cover across the studied areas. These findings provide valuable insights into the geographical distribution and host plant interactions of *G. ficorum* in Egypt, which can inform targeted control measures and improve fig production in different localities in Egypt.

INTRODUCTION

Egypt is a sizable nation with a landmass of 1,010,000 km^2, making it the westernmost country in the Middle East or Near East. The north shore of Egypt stretches 970 km eastward from Sallum to Rafah, with a breadth of 15 to 20 km running north to south (El-Hadidi, 1981). There are about 2,426 different kinds of plants documented in Egypt (Täckholm, 1974). The Mediterranean shore gets between 20 and 100 millimeters of rain per year and is home to roughly 1083 different plant species, (El Hadidi and Hosni, 1996). Among them, 255 species are known to exist in this region, 18 of which are endemic (El Hadidi and Hosni, 1996).

Ficus sp. is a widespread plant in the world due to its adaptability, ability to thrive in different climates, and human cultivation. The study of leaf-gall thrips and their host plant *Ficus* sp. has important implications for our understanding of mutualistic relationships and the role of insects in ecosystems. Leaf-gall thrips are a good model

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system for studying the ecology and evolution of mutualism (Miller *et al.*, 1998).

Freer-Smith *et al*. (2004) studied *Ficus* plant and found that it was able to establish itself in urban areas and grow in a variety of soils and climatic conditions in Egypt. Fig plant is able to tolerate high levels of salinity, making it a useful species for coastal reforestation Podda *et al.* (2017). They reported that fig plant is well-suited to the environmental conditions of Egypt and therefore, it has a wide geographic distribution throughout the country.

Leaf-gall thrips, *G. ficorum*, is a small insect species that belong to the order Thysanoptera (Family: Phlaeothripidae) and is known to cause galls, or abnormal growths, on the leaves of its host plant (e.g. the *Ficus sp.*) (Varatharajan, 2018 and Mound, 2020).

These galls are formed as a result of the insect's feeding and oviposition behavior, which disrupts the normal growth patterns of the fig plant leaves (Raman, 2007). Galls usually cause little if any serious harm to their hosts, the sap is sucked out of the leaves by thrips, which causes them to become yellow and spotty, with sometimes black streaks and a minor wrinkling (Köhler, 2008). Despite its economic importance little is known about the biology, behavior, and ecology of *G. ficorum* (Laborda *et al*., 2015). The current study aims to examine the factors that influence the growth and development of *G. ficorum* galls in fig plants (Ziouani, *et al*., 2019). Despite the fact that Gynaikothrips species are mostly found in Asia, the genus also contains several species that are found in Africa. *G. ficorum,* can grow wherever Ficus microcarpa L. is grown. (Denmark, 1967). The presence of galls on fig leaves has been documented in many regions of the world, including Asia (Mifsud, *et al*., 2012) and the Americas (Miller *et al*., 2019).

MATERIALS AND METHODS

Data were collected from sites located in ten Egyptian governorates i.e., 5 in the Delta region (Kafr El-Sheikh, Damietta, Menoufia, Qalyubia and Gharbia) 4 in the Upper Egypt (Elminya, Qena, Fayoum and red sea governorate) and one in the north Mediterranean Sea coast (Alexandria). The study sites were selected because they are known for their presence of fig trees (Fig. 1 and Table 1). The study sites are visited periodically, once a month, during the period from February 2021 to February 2023.

Table. 1: Plant species**,** study locations, coordinates, altitude, gall position, plant status, plant cover and number of galls per plant collected during the study from February 2021 to February 2023.

Plant species	Locality		Coordinate		Altitude (m)	Gall position	Plant status	Plant cover (CM^2)	No. of galls per plants
			Latitude	Longitude					
Ficus microcarpa	Alexandria	North Mediterranean coast	30.963998N	29.63159 E	14	plant leaf	galled	0.043	395
	Faiyum	Fayum Depression	29.507493N	30.887406 E	-18	plant leaf	galled	0.087	710
	Kafr El Sheikh	Nile Delta	31.180101N	30.904858 E	6	plant leaf	galled	0.12	480
	Gharbia		30.789928N	30.998627 E	10	plant leaf	galled	0.063	399
	Cairo		29.977407N	31.15178 E	18	plant leaf	galled	0.026	426
	Damietta		31.437108N	31.683403 E	2	plant leaf	galled	0.026	211
	Red Sea	Eastern desert	27.257798N	33.812478 E	12	plant leaf	galled	0.063	871
	Minya	Upper Egypt	28.094467N	30.763662 E	40	plant leaf	galled	0.026 4	145
	Asyut		27.203522N	31.184092 E	52	plant leaf	galled	0.087	327
	Qena		26.14676 N	32.69678 E	71	plant leaf	Un galled	0.11	0
No. of total galls									**3964**

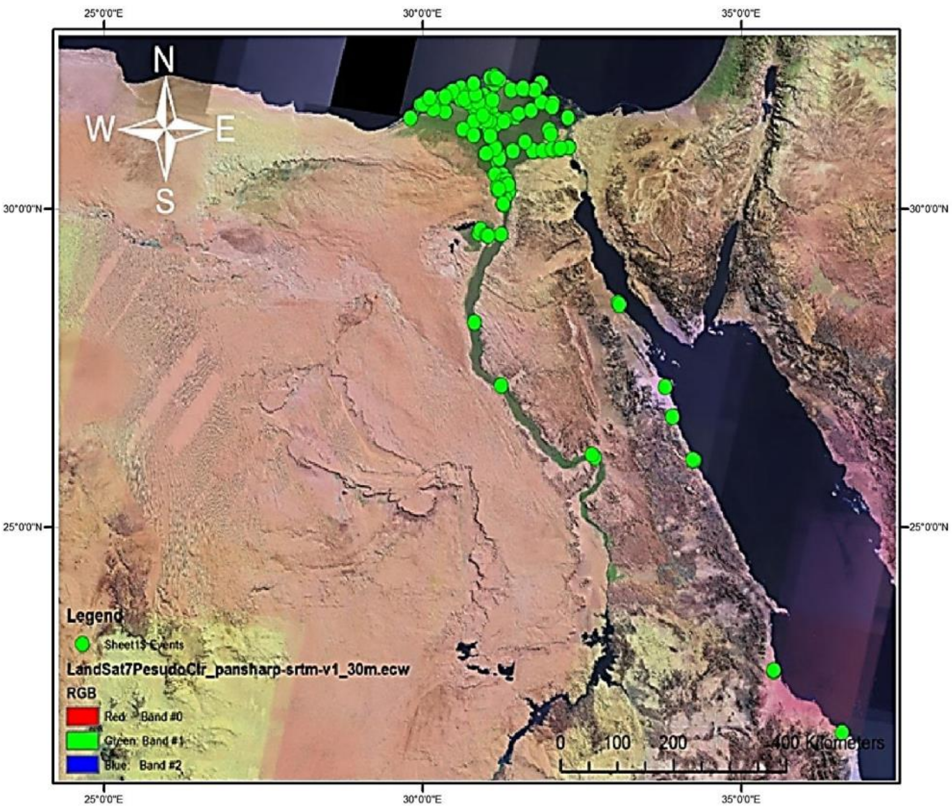

Fig. 1. Study area and collecting site locations in Egypt (Map source: Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community).

Sampling and Identification:

The plant leaves were collected and packed in bags, labeled and taken to the entomology laboratory of the Zoology Department, Faculty of Science, al-Azhar University for investigation. The number of immature stages and adult thrips were counted under a stereo microscope. *Thrips* found alive were quantified, preserved in 70% ethanol and later sent for identification. Each plant in the sample was measured for its width, length, and height using a tape meter, as well as the number of galls on various plant components. The collected plant samples were identified based on Boulos (1999).

Data Analysis and Programs:

All data was analyzed using the statistical package SPSS (PASW Statistics Ver.20). The Pearson correlation test was performed to examine the association between altitude, plant size, and the number of galls per plant. The average number of galls per plant was compared across regions using a one-way analysis of variance.

Mapping and Forecasting Plant Species Distributions:

The location of a fig species was recorded using a Garmin XL 12. Gall-inducing insect distribution was predicted using the MaxEnt method and environmental variable layers (elevation, temperature, and humidity) (Phillips *et al*., 2004, 2006).

The model made extensive use of raster grids. Climate information and topographical characteristics were divided into categories of environmental predictors. 19 bioclimatic variables from the worldclaim data collection according to (Hijmans *et al*., 2005).

Statistical Validation of the Model:

The data was randomly partitioned into three categories: species predictions ("training data"), model development ("testing data"), and model assessment ("evaluation data") ("extrinsic and independent test data sets"). The area under the curve (AUC) was determined with the aim of verifying the model's accuracy statistically. Accuracy is quantified by the area under the curve (AUC) (Phillips, 2016). The AUC might be anything from 0 to 1. An AUC of 0.5 indicates a typical model, whereas an AUC of 1 indicates a perfect one (Phillips *et al*., 2004 and Phillips *et al*., 2006).

The jackknife test was used to identify the most influential contributing components. Additionally, Maxent provided the relative importance of each variable in the final model as a percentage of the total gain to the model (Phillips *et al.*, 2006).

Plant Cover:

Vegetation coverage Is characterized by diversity and species abundance fluctuation (Hamza *et al.*,2023).

RESULTS

Insects that Induced Galls:

Young leaves of *Ficus microcarpa* L. f. (Rosales: Moraceae) are attacked by *G. ficorum* (Marchal) (Thysanoptera: Phlaeothripidae) (Fig. 2), causing leaf curling and developing of leaf galls (Fig. 3) and fresh galls start out green, but after the gall midges emerge, they become yellow and may stay connected to the plant until the next season (Fig. 4).

Fig. 2:(A) Adult and (B) nymph of *Gynaikothrips ficorum* (Marchal)

Fig. 3: (C: leaf galls) of *Ficus microcarpa* (Rosales: Moraceae) and (D: magnified galls)

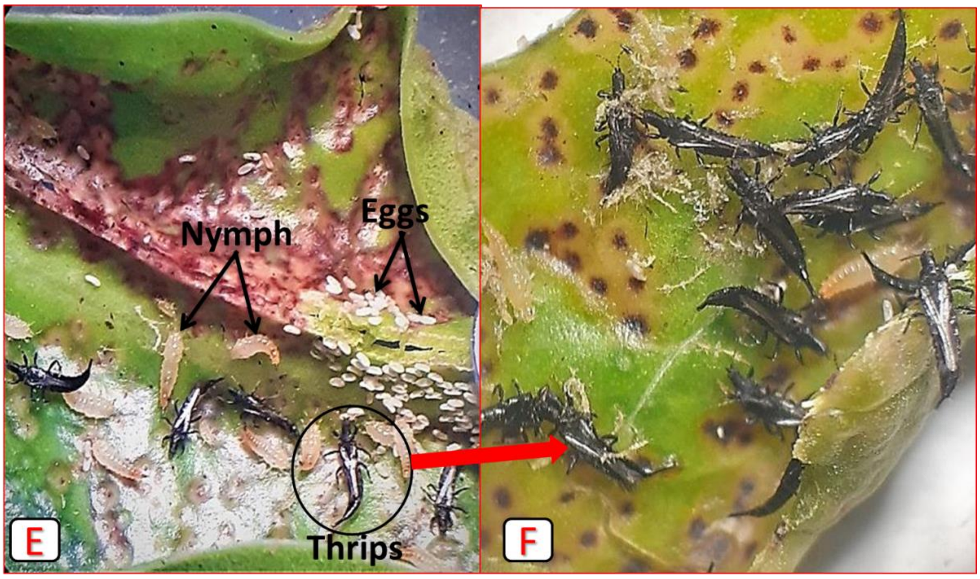

Fig. 4: (E: Nymph and adult of thrips inside the leaf gall of *Ficus microcarpa* and (F: magnified thrips)

Factors Affecting the Distribution of Insect-Causing Galls:

1. Correlation between the Number of Galls per Plant, Plant Cover, and Altitude:

Gall density per plant was positively correlated with plant cover across the studied areas. In the study areas, however, no correlation between gall density and plant height was found (Fig.5).

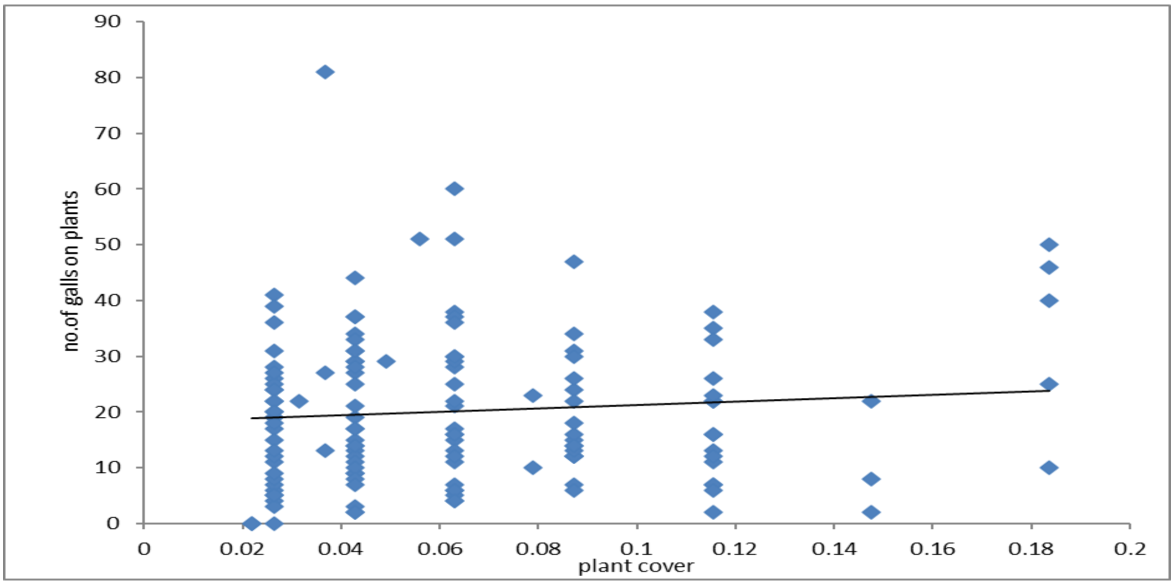

Fig.5: The relationship between galls on ficus and the plant cover within the study localities.

2. The Number of Galls Generated on Ficus and Their Altitude and Plant Cover in Various Locations:

The number of galls induced on Ficus showed a significant difference among various localities (Fig.6).

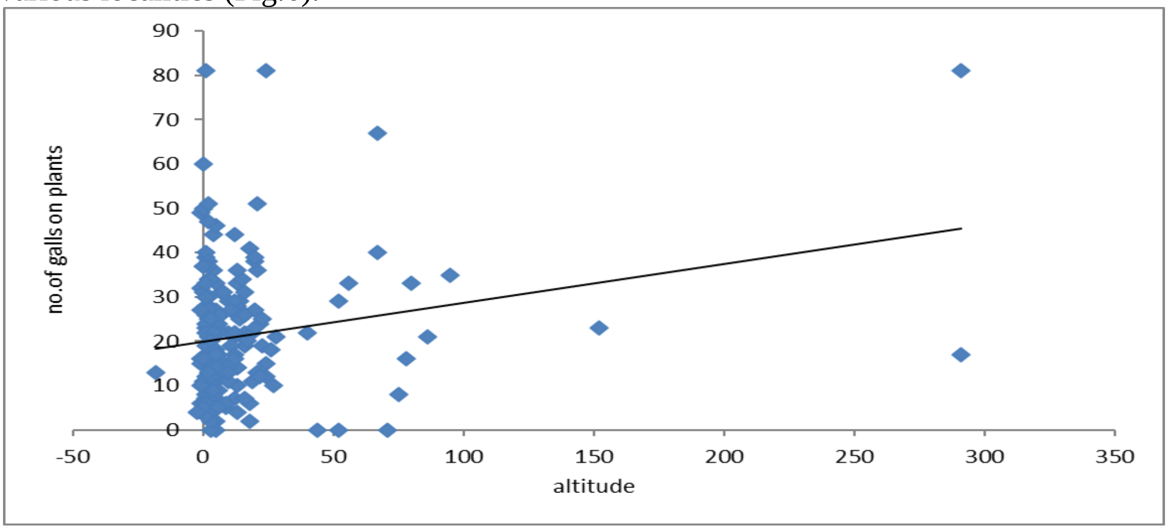

Fig.6: The relationship between galls on ficus and altitude, plant cover within the study localities.

Spatial Prediction Model of *Ficus microcarpa* :

Ficus microcarpa L. f. (Rosales: Moraceae): An Estimate of Its Potential Habitat in Egypt. MaxEnt's Ficus model may be seen in (Fig. 7). The locations along the northern shore of the Nile Delta are where the species Ficus is most likely to have established its native home. To train, six records of presence were utilized, and to test, two were used. Figure 8 shows that Ficus has excellent discrimination, with an AUC of 0.979 for the training set and 0.980 for the test set, with a standard deviation of 0.001. There was a bare minimum of 48,778 training points. At this cutoff, the absence rate for test sites was 0.000 and the proportion of anticipated areas was 0.001. The model performs better than a random model in classifying the test points ($p < 0.001$).

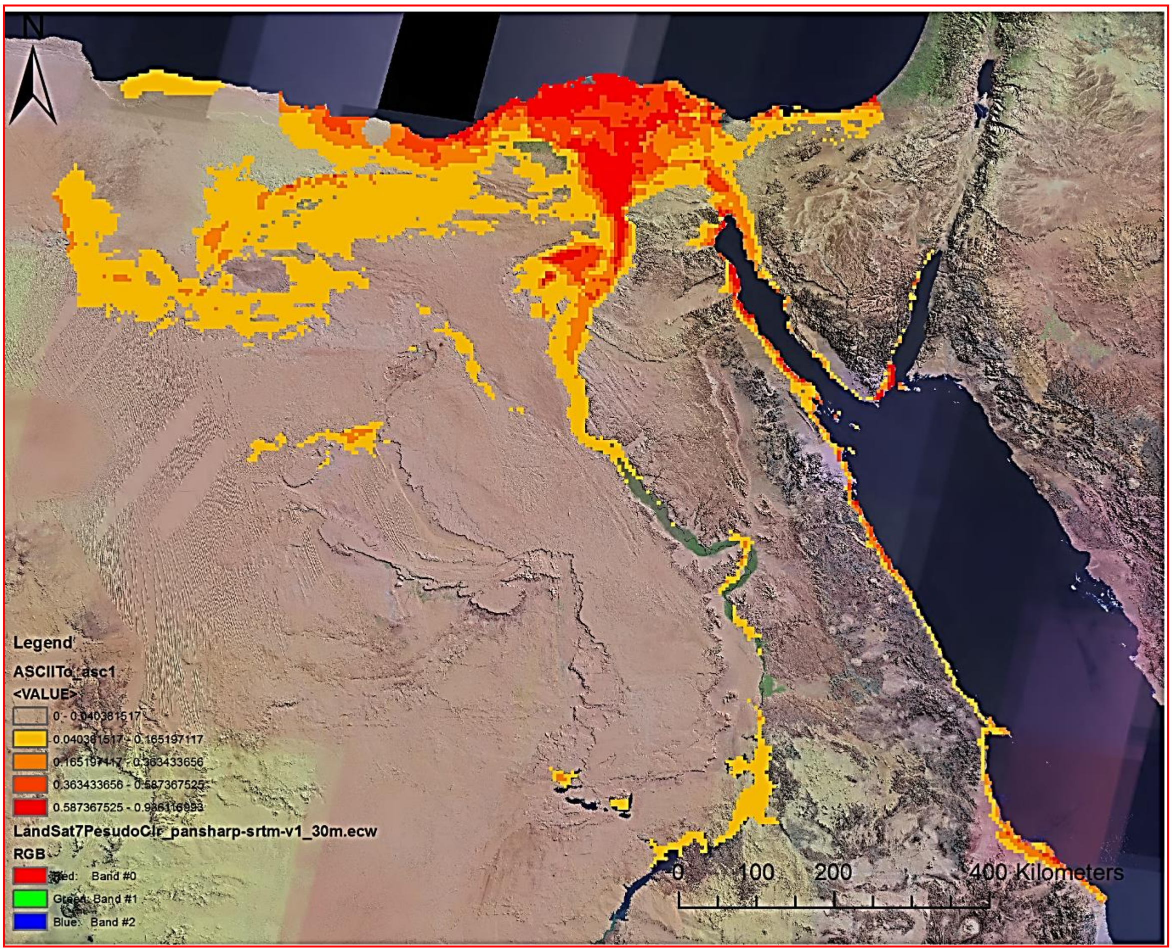

Fig. 7: The predicted distribution range of *Ficus microcarpa* according to the MaxEnt model. (Map source: IESR, GIS unit & google map https://www.google.com.eg/maps/@27.4846068,31.3939550,6z).

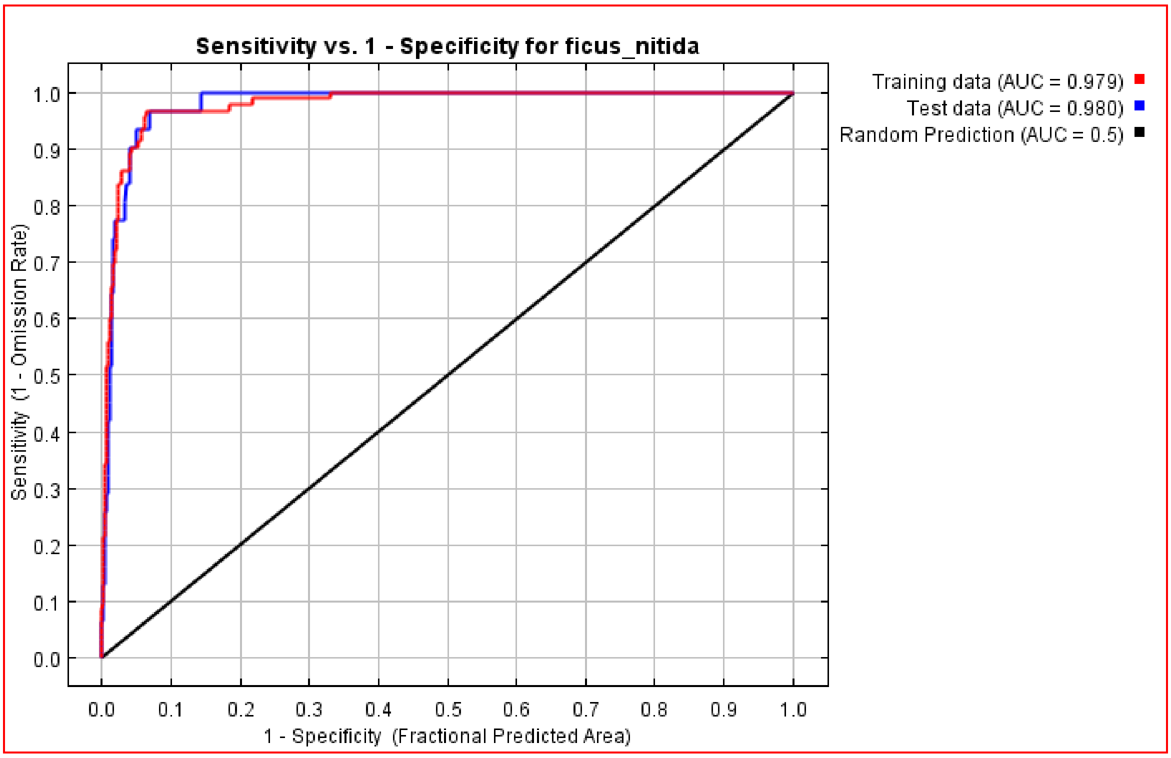

Fig.8: Training data (AUC = 0.979) and test data (AUC = 0.980) compared to random prediction (AUC = 0.5) in the receiver operating characteristic (ROC) curve for the representation of the MaxEnt model for *Ficus microcarpa.*

DISCUSSION

Plant components that are rapidly developed, such as stems and leaves, are often the targets of gall-inducing microbes (Price, 1991). Current research indicates that the leaves are the most vulnerable part of the plant to gall induction. It's possible that the leaves' conducive environment for gall formation is to blame (De Bruyn, 1994). In addition, gall-causing insects prefer the leaves to other sections of the plant because of their higher economic value (Whitham, 1978). Gall-inducing insects prefer big plants over small ones, as shown by the positive correlation between gall density and plant cover in the present research.

It has strong connections to the materials provided by enormous plants, which bolsters the theory (Feeny, 1975). This is consistent with the results of Daniela *et al.* (2008) discovery of a similar association for the Indonesian flora, which showed a positive link between the number of galls and the biomass and branch count of the host plant. The results also support the claims made by Arajo *et al*. (2006) who hypothesised that more complex plant architecture would attract a wider variety of insect species, including those that produce galls.

The results provide credence to Wright and Samways' (1996, 1998) theory that a wide variety of plant species might be responsible for the evolution of gall-forming organisms. However, the results did not back up the claim made by Fernandes and Price (1988) that the variety of gall-producing insects is unrelated to the number of plant species. Herbivorous insects are more enticing and persuasive because more structurally complex plants sustain a greater variety of herbivorous insects by providing additional microhabitats, locations for oviposition, and shelter from natural predators (Lázaro-González *et al.*, 2017).

Precipitation of the Wettest Quarter BIO16, Temperature Seasonality BIO4, Precipitation of the Warmest Quarter BIO18, Precipitation of the Wettest Month BIO13, Precipitation Seasonality (Coefficient of Variation) BIO15, Min Temperature of the Coldest Month BIO18, and Altitude all demonstrated high sensitivity in ficus. This supports the findings of (Blanche, 2000; Butterill & Novotny, 2015; Da Costa *et al*., 2011).

Finally, according to our results, further research must be conducted to better understand the potential impact of this pest on agricultural crops in Egypt. The predicted distribution of *G. ficorum* suggests that it may become a significant threat to crops in certain regions, and therefore, monitoring programs should be established to detect its presence early on. Additionally, efforts should be made to identify effective management strategies for controlling this pest, such as biological control methods or cultural practices that reduce its impact on host plants. Overall, proactive measures should be taken to prevent the spread.

CONCLUSION

The interactions between leaf-gall thrips and Ficus host plants are complex and can have significant impacts on plant health and productivity. Effective management strategies require a thorough understanding of these interactions and the use of a combination of control methods. Predictive modeling techniques, such as Maxent, can provide valuable insights into the distribution and interactions of these pests, helping to inform pest management strategies and improve overall plant health.

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ARABIC SUMMARY

التنبؤ بالتوزيع الجغرافي لحشرة التربس
والتفاعل مع النباتات المضيفة في مصرGynaikothrips ficorum (Marchal)

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تعتبر حشرة التربس المسببة للأورام النباتية من الآفات الغازية التي تسبب أضرارًا كبيرة لبعض المحاصيل في مصر. إن فهم التوزيع الجغرافي لهذه الآفة وعلاقتها مع النباتات المضيفة أمر بالغ الأهمية للاستراتيجيات الفعالة. في هذه الدراسة، استخدمنا النمذجة البيئية المتخصصة للتنبؤ بالتوزيع الجغرافي المحتمل لـلحشرة في مصر بناءًا على المتغيرات البيئية. قمنا أيضًا بدراسة التفاعل بين الحشرة وواحدا من النباتات المضيفة لها من خلال تحليل معدل الإصابة وشدة الضرر باستخدام تقنية ماكسنت ووجد ان الحشرة سريعة الانتشار في معظم أنحاء مصر، مع أعلى ملاءمة في منطقة دلتا النيل. بالإضافة إلى ذلك، وجدنا هذا النوع من النباتات وهو التين الميكروكاربا أكثر عرضة للإصابة والضرر بواسطة الحشرة، مما يسلط الضوء على أهمية اختيار مبيدات ذات فاعلية عاليه للآفات وأيضا أظهرت النتائج أن عدد الاوراق المصابة في كل نبات كان مرتبطا بشكل ايجابي مع الغطاء النباتي في مناطق الدراسة وتوفر هذه النتائج رؤى قيمة حول التوزيع الجغرافي والتفاعلات النباتية المضيفة لحشرة التربس المسببة للأورام النباتية في مصر، والتي يمكن أن تفيد تدابير المكافحة المستهدفة وتحسين إنتاج هذا النبات في مناطق مختلفة في مصر.