3rd Inter. Conf. Virol., Cairo Univ. Center, Nov. 24-25, 2010
Egyptian J. Virol., SP. Issue, 513-532, 2010

THE LIMITING OF CLIMATIC FACTORS AND PREDICTING OF SUITABLE HABITAT FOR CITRUS GUMMY BARK DISEASE OCCURRENCE USING GIS

[33]

Sofy[1]*, A.R.; Mousa[1], A.A.; Soliman[2], A.M. and El-Dougdoug[3], Kh.A.

ABSTRACT

Gummy bark disease is a disorder of sweet orange on sour orange rootstock in Egypt. There is an importance for hot-growing temperatures to symptom development of citrus viroids. The geographical distribution of the gummy bark disease in some world countries depend on high temperatures for viroid-symptom expression. So, correlation between climatic factors and gummy bark disease through GIS is studied. We designed a satellite map for the gummy bark disease distribution all over the world using the previous registered results. Superimposed maps of BIOCLIM annual Min-temperature, Max-Temperature and the points distribution, indicated that gummy bark disease naturally occurs in the low temperature zones range from 8–18°C at winter and from 27-38°C at summer season where the altitude ranged from -351 to 1320 m. A novel method called maximum entropy distribution modeling was used for predicting potential suitable habitat for gummy bark disease in Egypt using occurrence records. The Maxent model's internal jackknife test of variable importance showed that altitude and mean temperature of driest quarter are the most important predictors of citrus gummy bark disease-habitat distribution.

Key words: Citrus, Gummy bark, Viroids, GIS, Biodiversity, Maxent, Egypt.

[1]Botany and Microbiology Department, Faculty of Science, Al-Azhar University, 11884 Nasr City, Cairo, Egypt.
[2]Plant Virus and Phytoplasma Research Section, Plant Pathology Institute, Agriculture Research Center, Giza, Egypt.
[3]Virology Lab., Agric. Microbiology Department, Faculty of Agriculture, Ain Shams University, 11241 Cairo, Egypt.
*ahmd_sofy@yahoo.com

INTRODUCTION

Gummy bark is a disorder of trees of sweet orange on sour orange rootstock in Egypt was described by **Nour-Eldin (1956; 1959)** as phloem discoloration of sweet orange. Affected sweet orange trees are usually stunted to varying degrees and sometimes severely reduced in size. When the bark of affected trees is scraped, a line of reddish-brown, gum-impregnated tissue can be seen around the circumference and especially near the bud union **(Nour-Eldin, 1956; 1959).** Most frequent occurrence of citrus gummy bark disease has been recorded in North Africa and the Middle East countries including Egypt, Saudi Arabia, Sudan, Libya, Iran, Morocco, Greece and Turkey on different cultivars i.e. Baladi, Aboussoura, Valencia, Hamlin, Washington navel, Sukkary, Khalili white and Egyptian blood (**Çinar *et al.*, 1993; Bové, 1995**).

Etiology of this disease is unknown. Because of its graft-transmissibility character, the disease was first considered to be caused by a virus. Recently, citrus gummy bark (CGB) is correlated to viroid (**Önelge *et al.*, 2004; Sofy *et al.*, 2010**). Geographical distribution of the gummy bark disease has only been observed in countries where high temperatures are there to favor viroid-symptom expression (**Roistacher, 1991; Önelge *et al.*, 1996**).

The 20th century has a significant increase of Earth's average temperature, rising sea levels, and extreme weather events (**IPCC, 2001**). Moreover, scientists predict that trend will continue elevating throughout the 21st century (**IPCC, 2001**). These changes could pose a significant threat to global biodiversity. As early as 1924, Joseph Grinnell noted that sudden environmental changes could lead to species extinction (**Grinnell, 1924**). Species distribution, and changes in population structure and abundance as well could be explained as a warming climate effect (**Parmesean and Yohe 2003; Root *et al.*, 2003**).

This work aimed at: (1) predict suitable-habitat distribution for citrus gummy bark disease in Egypt using a small number of occurrence records, and (2) identify the environmental factors associated with CGB habitat distribution. Different approaches have been used A) CGB occurrence records, B) GIS (geographical information system), C) environmental layers (bioclimatic and topographic), and D) the maximum entropy distribution modeling (**Phillips *et al.*, 2006**) to predict potential suitable-habitat for CGB occurrence and distribution.

MATERIALS & METHODS

1) Mapping for locations of citrus gummy bark disease occurrence in Egypt through GIS:

At each site a GPS fix was recorded in decimal degrees and datum WGS84 using Trimble Navigation Scout^{M+} Edition 3.00A receiver. The fix was recorded to the fifth decimal digit. Arc View GIS 9.2 software was used to plot the study sites.

2) Middle East mapping for distribution of gummy bark disease through GIS:

The gummy bark disease was registered at (Dora and Al Mansuriya) Iraq, (Muscat, Salalah and Tanuf) Oman, (Turabah, Najran and Bishah) Saudi Arabia, (Al Ladhqiyah and Ugarit) Syria, (Kassala, Atbara, Nyala and Zalingei) Sudan, (Tarnab) Pakistan, (Al Hamraniyah) United Arab Emirates, (Mukayris, Lawdar, Mudiyah, Seiyun and Tarim) Southern Yemen, (Marib and Harib) Northern Yemen, (Dörtyol, Adana, Erzin, Mersin, Alata, Antalya, Köyceğiz and Yeşilkent) Turkey and finally (Kalyobiya and Fayoum) Egypt (**Bové, 1995; Önelge *et al.*, 1996, Bernad *et al.*, 2005; Mohamed *et al.*, 2009; Sofy *et al.*, 2010**). At each site a GPS fix was recorded in decimal degrees and datum WGS84 using Google Earth Pro. software (Ver. 4.2.0180.1134 (beta)) (http://earth.google.com/). The fix was recorded to the fifth decimal digit. Arc View GIS 9.2 software was used to plot the study sites.

3) Environmental data:

Climate data were obtained from the Worldclim bioclimatic database, which include 19 variables of precipitation and temperature for the periods at 1950–2000 (**Hijmans *et al.*, 2005** available at http://www.worldclim.org).

4) *DIVA*-GIS software:

DIVA-GIS software is a free computer program for mapping and geographic data analysis. BIOCLIM is a bioclimatic prediction system which uses surrogate terms (bioclimatic parameters) derived from monthly mean climate estimates, to approximate energy and water balances at a given location (**Nelson** ***et al.*****, 1997**). The present version can produce up to 19 bioclimatic parameters based on the climate variables i.e. maximum and minimum temperatures, rainfall, solar radiation, pan evaporation and altitude. If some of these climate variables are unavailable, fewer bioclimatic parameters are produced. BIOCLIM uses monthly or weekly values of maximum and minimum temperature.

5) Predicted distribution range of the gummy bark disease in Egypt:

The Maxent model software predicted a distribution range that visually matched with the observed location. Regions of higher concentration of presence points were accurately the areas predicted as of highest presence probability. Receiver operating curve (ROC) analysis was used to evaluate how well the Maxent model compared to random prediction. The area under the ROC function (AUC) is an index of performance because it provides a single measure of overall accuracy of distribution models which ranges from 0 to 1. An AUC of 0.5 indicates a model that is no better than random prediction, while an AUC of 1 indicates a perfect model for prediction (**Phillips** ***et al.*****, 2004, 2006**). The accuracy is tested against the species records that were used to build the model. In maximum entropy literature models are selected for their higher (AUC) (**Phillips** ***et al.*****, 2004, 2006**). Also, the jackknife test was used to indicate different variables. Jackknifing could detect contribution of individual variables to the model.

Maxent utilizes a statistical mechanics approach, called maximum entropy to make predictions from incomplete information. It estimates the most uniform distribution. Detailed descriptions of the Maxent's methods can be found in **Phillips** ***et al.*** **(2004, 2006)**. Maxent's predictions are 'cumulative values', of probability value % (**Phillips** ***et al.*****, 2004, 2006**). The algorithm is implemented in a stand-alone, freely available application. In this study, each environmental variable (linear features) and its square (quadratic features) were used, because Maxent utilize pseudo-absence values.

RESULTS

1- Citrus gummy bark occurrence in Egypt and in the Middle East:

Presence or absence of citrus gummy bark viroid using GPS was recorded in different locations belong to four governorates Kalyobiya (Qanater and Al-Sahel regions), Fayoum (Sanhur tribal region), South Sinai and Behera (Ali Mubarak and Al-Shgaa (22) regions) **(Figure 1)**. Occurrence records of citrus gummy bark disease in two governorates i.e. Kalyobiya and Fayoum has been confirmed by biological and molecular analysis.

Potential geographic factors distribution of gummy bark disease using its current distribution and data on a range of environmental parameters has been predicted. Two computational approaches i.e. *DIVA*-GIS and Maxent attempts were used to identify the habitat that affects gummy bark disease occurrence. Data obtained from *DIVA*-GIS software showed the optimum range of bioclimatic factors in different geographical regions of four governorates which we recorded the presence or absence of citrus gummy bark disease among the different sites **(Table 1)**.

The superimposed maps **(Figure 2-A & B)** of BIOCLIM annual Min-temperature, Max-temperature and the points distribution indicated that, gummy bark disease incidence in Kalyobiya and Fayoum naturally occur in the low temperature zones range from 11–14°C at winter and from 28-31°C at summer season **(Figure 2 and Table 1)**. Absence of gummy bark disease in Behera and South Sinai has been confirmed by the relatively low temperature zones range from 14–17°C at winter and from 24-28°C and 28-31°C respectively at summer season. **Figure (3)** indicate rainfall is very low and occurs in winter season which temperature is low. Summer season where temperature is high has no rain.

Dendrogram produced from the cluster analysis based on the mean temperature of driest quarter which consider the most important variable factor, present in **Figure (4).** It indicates that; studied locations for citrus gummy bark disease occurrence have an average dissimilarity percentage of 84 and therefore, the locations were delimited into two distinct groups **(Figure 4)**. The first group has two locations Al-Shgaa and Ali Mubarak, Behera governorate.

They are linked together in the same level of 50. The second group has South Sinai and Fayoum locations delimited at a level of 68 in which they are linked with Al-Sahel and Qanater locations in a level of 33. Also, last group has two Al-Sahel and Qanater locations where they are linked together in the same level of 16 (**Figure 4**).

Depending on the occurrence records of this disease; as described in the materials and methods. The GPS points were collected through the google earth software and Arc View GIS 9.2 software was used to plot sites in the Middle East (**Figure 5**).

The superimposed maps (**Figure 6-A and B**) of BIOCLIM annual Min-temperature, Max-temperature and the points distribution indicated that gummy bark disease naturally occurs in the low temperature zones range from 8–18°C at winter and from 27-38°C at summer season where the altitude ranged from -351 to 1320 (**Figure 6-C**).

2-Maxent modeling for predicting suitable habitat for gummy bark disease in Egypt:

The Maxent model predicted potential suitable habitat for gummy bark disease with high success rates of AUC (0.999) which measure the accuracy of distribution models (**Figure 7**). The Maxent model's internal jackknife test of variable importance showed that, altitude and mean temperature of driest quarter were the two most important predictor factors of gummy bark disease habitat distribution (**Figure 8; Table 2**). These variables presented the higher gain (that contains most information) compared to other variables (**Figure 8; Table 2**). Most suitable habitat for gummy bark disease was predicted in Egypt as shown in **Figure (9)**, and its distribution is quite fragmented.

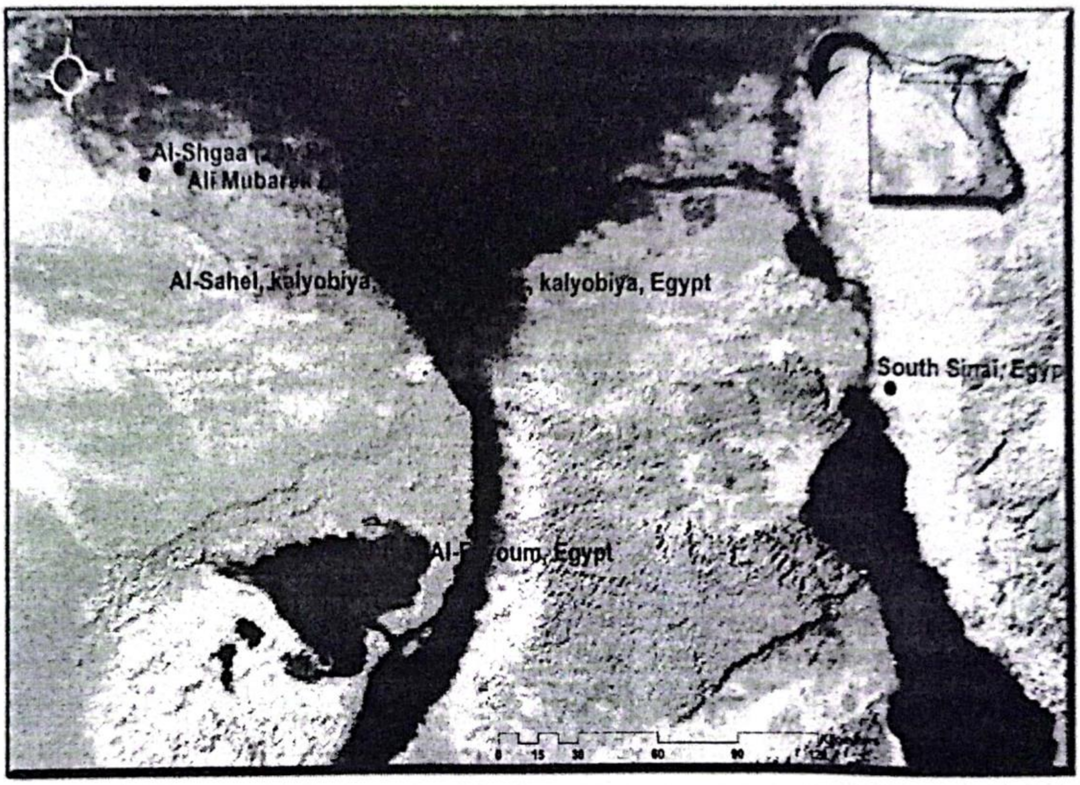

Figure 1. Location GIS map of study areas.

Table 1. The predicted climate data for the studied regions including different phenomena satisfactorily in Egypt.

Bioclimatic variable	Regions					
	Al-Sahel	Qanater	Sanhur	South Sinai	Ali Mubarak	Al shgaa (22)
(1) Annual Mean Temperature	20.9	20.9	21.1	22.4	20.6	20.5
(2) Mean Monthly Temperature Range	14.2	14.2	15.4	12.5	12.5	12.4
(3) Isothermality (2/7) (* 100)	50.5	50.5	48	45.8	48.5	48.2
(4) Temperature Seasonality (STD * 100)	538.5	538.5	631.6	561.6	528.8	529.8
(5) Max Temperature of Warmest Month	34.7	34.7	36.4	36.2	33.3	33.1
(6) Min Temperature of Coldest Month	6.6	6.6	4.4	8.9	7.5	7.4
(7) Temperature Annual Range (5-6)	28.1	28.1	32	27.3	25.8	25.7
(8) Mean Temperature of Wettest Quarter	13.9	13.9	14.7	16.8	15.4	15.3
(9) Mean Temperature of Driest Quarter	27.1	27.1	27	28.8	26.6	26.5
(10) Mean Temperature of Warmest Quarter	27.1	27.1	28.2	28.8	26.6	26.5
(11) Mean Temperature of Coldest Quarter	13.9	13.9	12.7	15.2	13.9	13.8
(12) Annual Precipitation	22	22	10	22	65	66
(13) Precipitation of Wettest Month	5	5	3	5	18	19
(14) Precipitation of Driest Month	0	0	0	0	0	0
(15) Precipitation Seasonality (CV)	106.2	106.2	123.6	95.4	118.2	123.2
(16) Precipitation of Wettest Quarter	14	14	6	11	44	46
(17) Precipitation of Driest Quarter	0	0	0	0	0	0
(18) Precipitation of Warmest Quarter	0	0	0	0	0	0
(19) Precipitation of Coldest Quarter	14	14	6	9	39	40

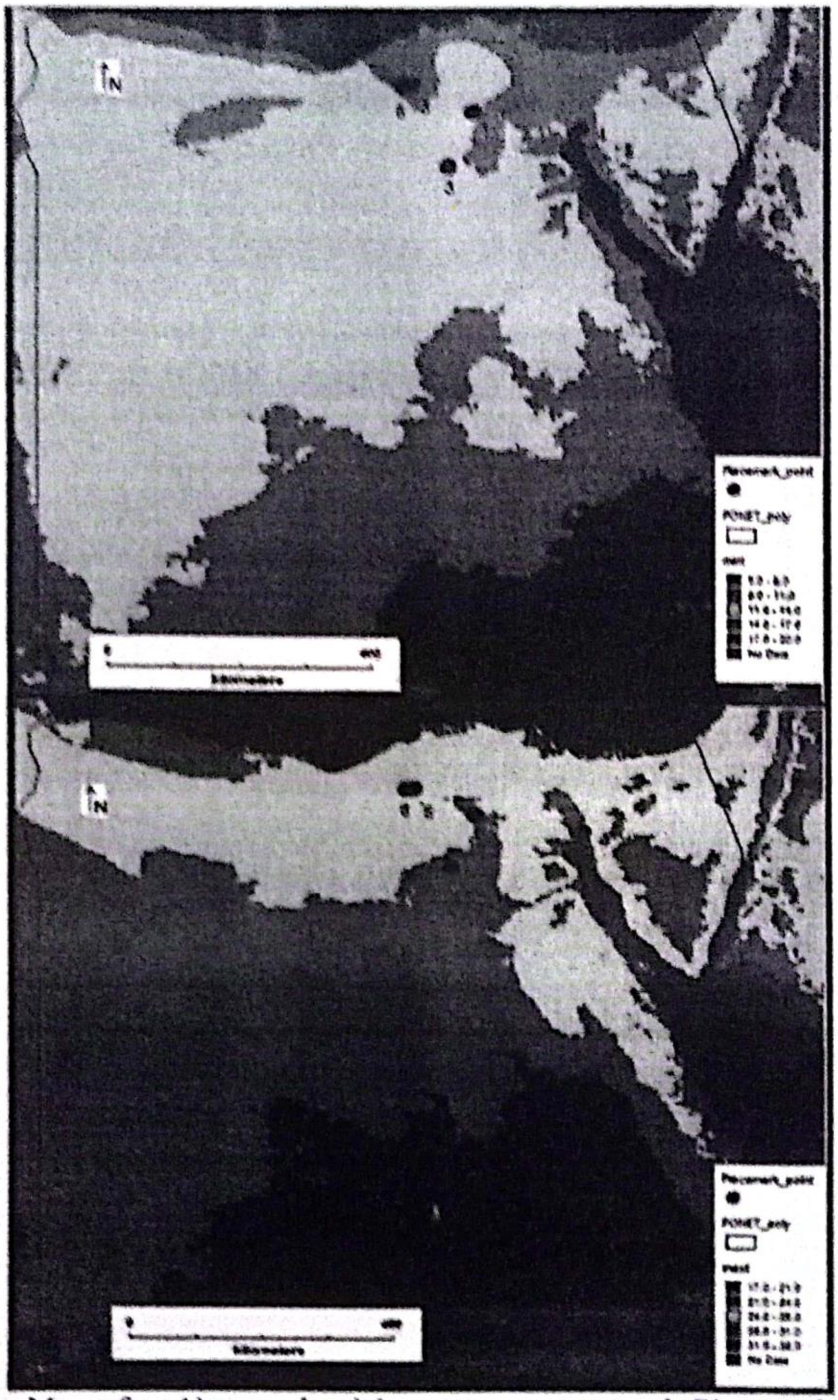

Figure 2. Maps for A) annual minimum temperature and B) annual maximum temperature within the study regions.

Key: 1) Al-Sahel, 2) Qanater, 3) Sanhur, 4) South Sinai, 5) Ali Mubarak and 6) Al-Shgaa (22).

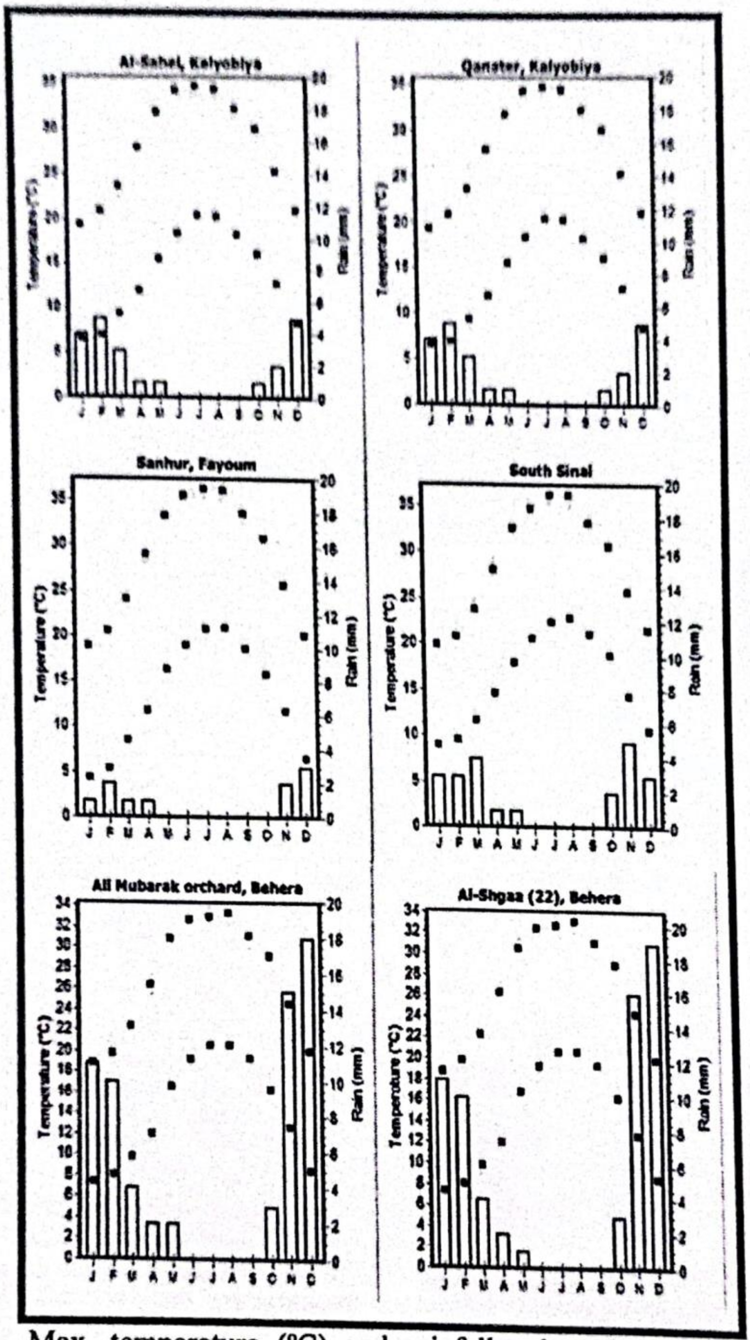

Figure 3. Min., Max. temperature (°C) and rainfall values (mm) for the 6 studied locations as habitats of citrus gummy bark disease occurrence.

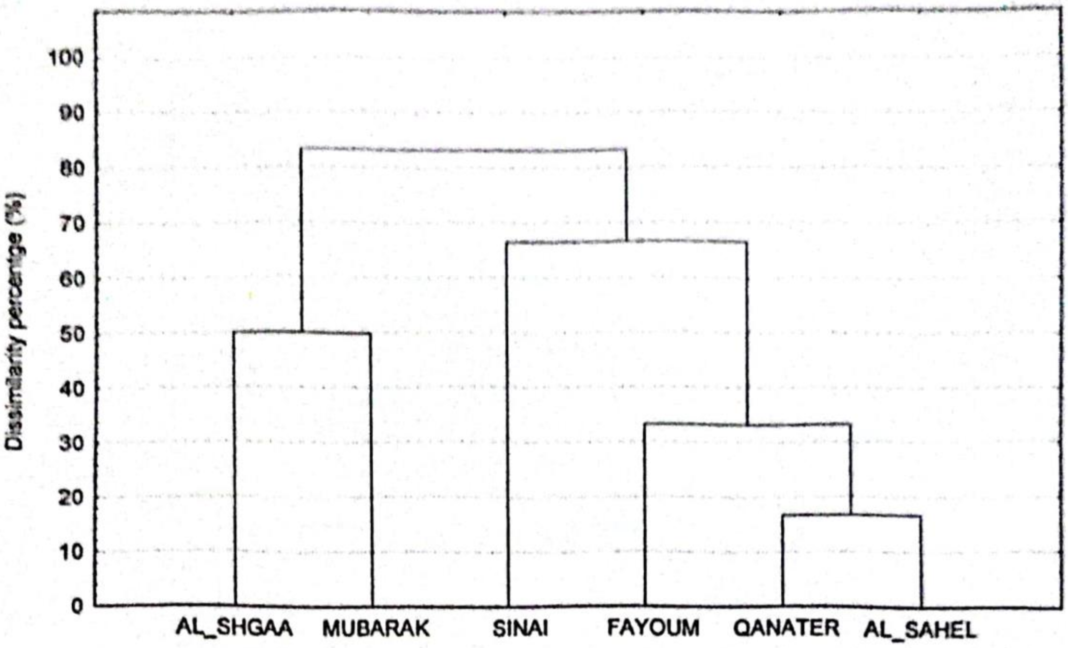

Figure 4. UPGMA-dendrogram based on mean temperature of driest quarter illustrating similarity & dissimilarity percentage between the studied regions for citrus gummy bark disease in Egypt.

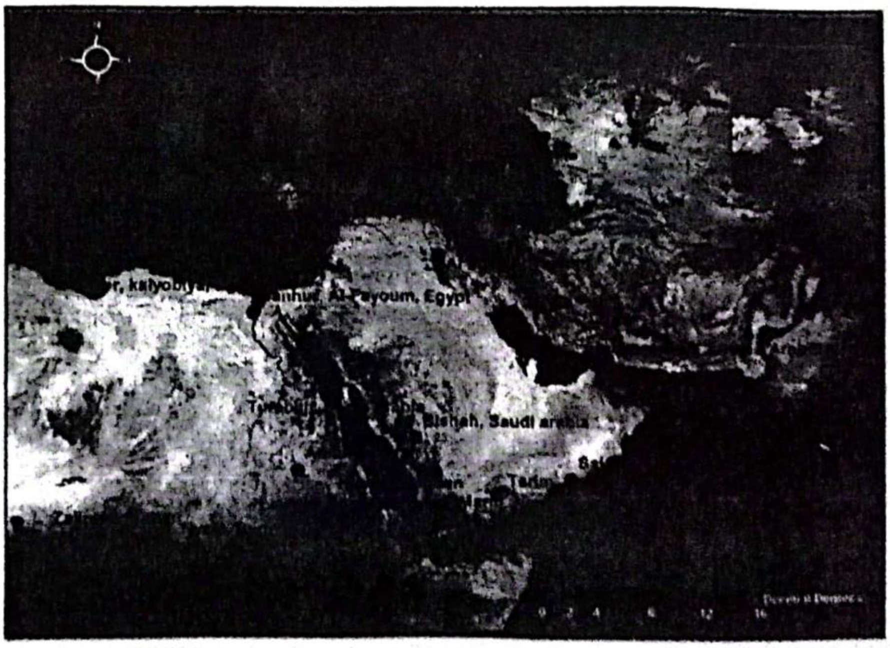

Figure 5. Location GIS map of gummy bark disease all over the world.

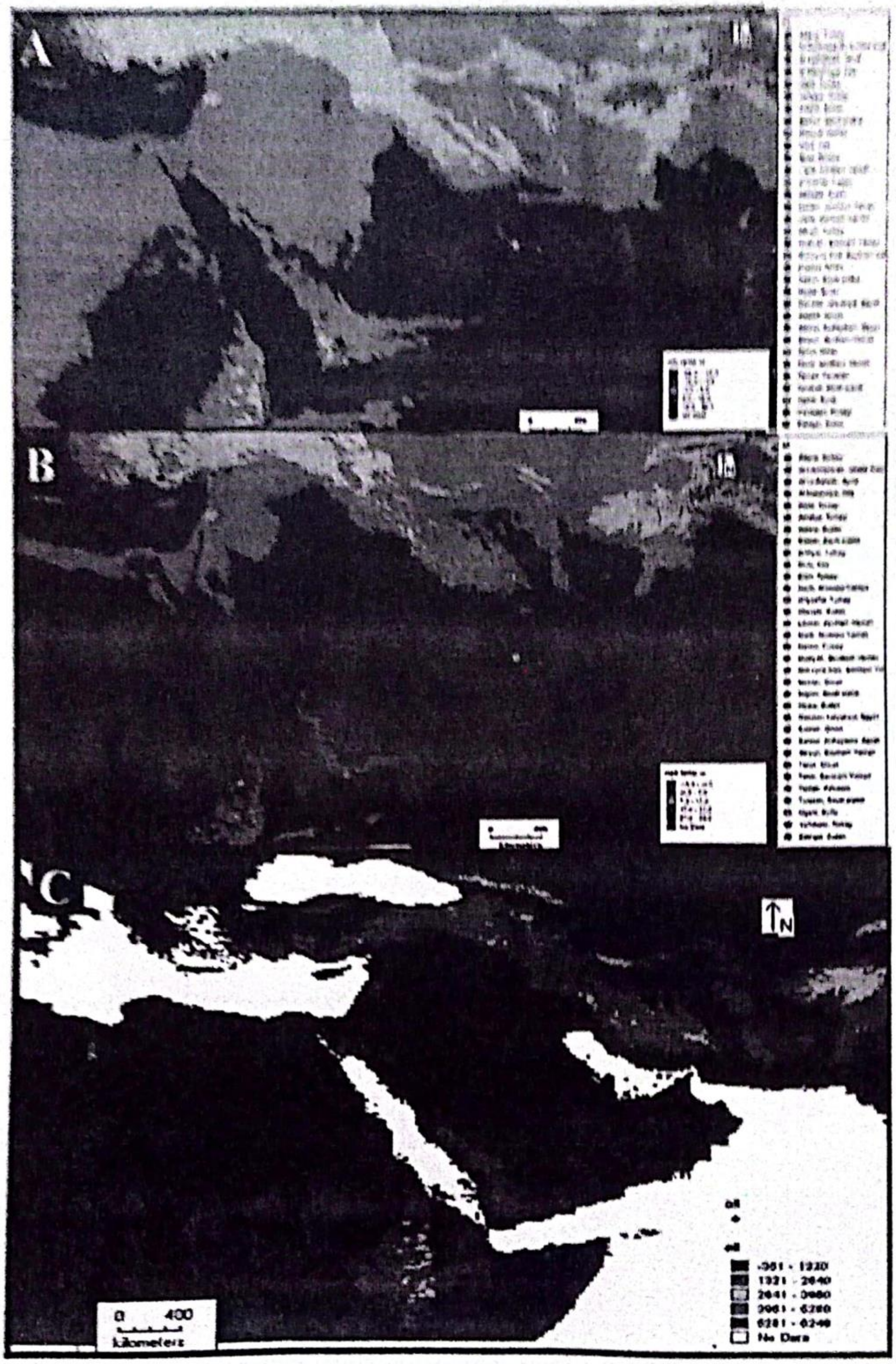

Figure 6. Maps for A) annual minimum temperature, B) maximum temperature and C) altitude within the study gummy bark disease regions all over the world.

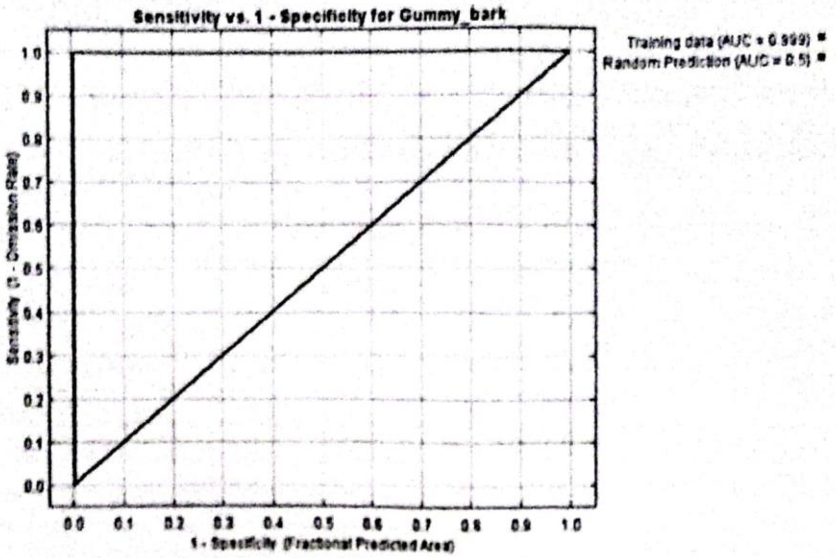

Figure 7. Results of training data (AUC = 0.999) compared to random prediction (AUC = 0.5) in the receiver operating characteristic (ROC) curve for representation of the Maxent model for gummy bark disease

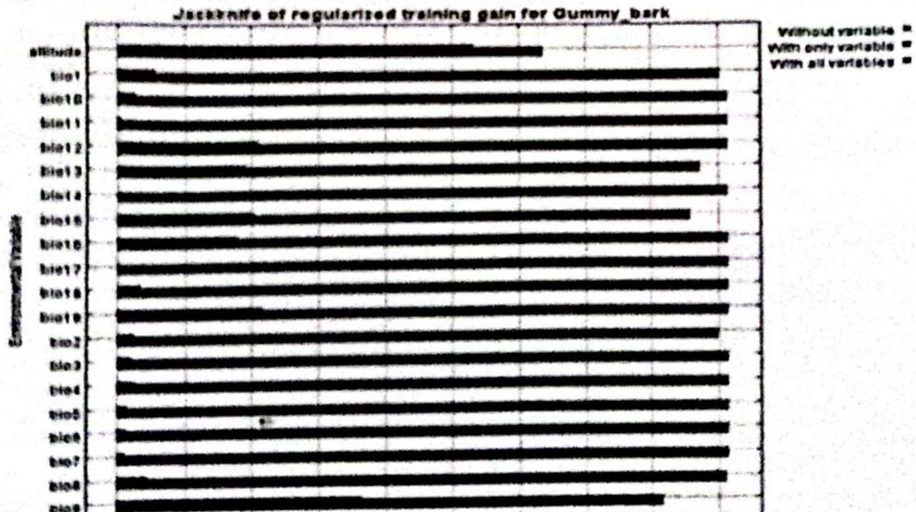

Figure 8. Results of jackknife evaluations of relative importance of predictor variables for gummy bark disease Maxent model.

Table 2. Selected environmental variables and their percent contribution in Maxent model for gummy bark disease in Egypt.

Environmental variable	Percent contribution (%)
Altitude	36.2
Mean temperature of driest quarter (Bio 9)	34
Precipitation of wettest month (Bio 13)	9.3
Mean temperature of wettest quarter (Bio 8)	7.2
Precipitation seasonality (Bio15)	5.7
Isothermality (Bio3)	2.4
Min temperature of coldest month (Bio 6)	1.2
Mean temperature of warmest quarter (Bio10)	1
Mean monthly temperature range (Bio 2)	0.8
Precipitation of coldest quarter (Bio 19)	0.7
Annual precipitation (Bio 12)	0.6
Annual mean temperature (Bio 1)	0.5
Temperature annual range (Bio 7)	0.4
Precipitation of driest month (Bio 14)	0
Precipitation of wettest quarter (Bio 16)	0
Precipitation of driest quarter (bio 17)	0
Mean temperature of coldest quarter (Bio 11)	0
Precipitation of warmest quarter (Bio 18)	0
Temperature seasonality (Bio 4)	0
Max temperature of warmest month (Bio 5)	0

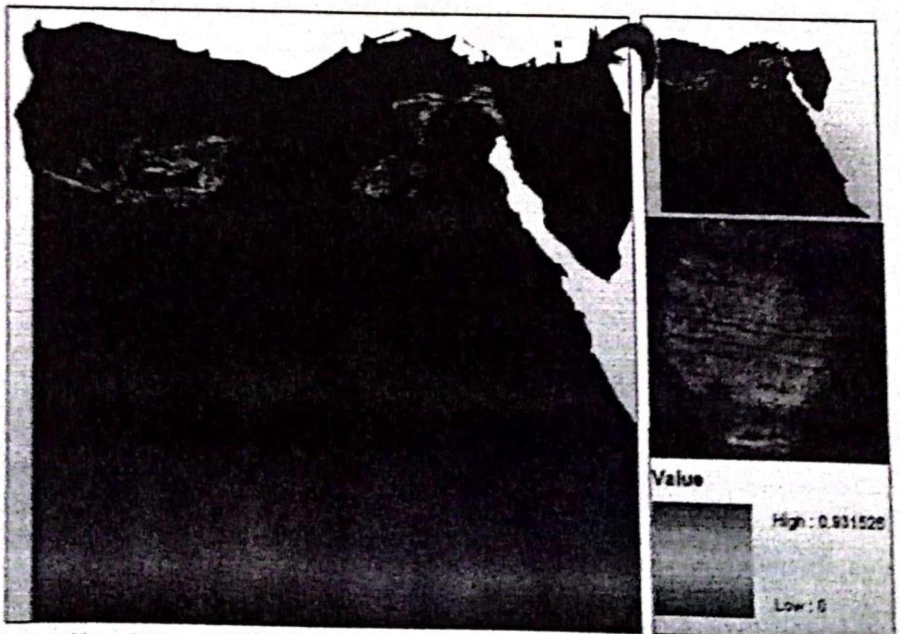

Figure 9. Predicted potential suitable habitat for gummy bark disease in Egypt.

DISCUSSION

Among graft transmissible diseases in Egypt and Mediterranean countries; citrus psorosis disease, citrus exocortis disease, citrus cachexia disease and citrus gummy bark disease are of the most serious diseases (**El-Dougdoug, *et al.* 1993; 1997; 2009, Sofy *et al.*, 2010**). The geographical distribution of the gummy bark disease, when high temperatures are favor viroid-symptom expression has been reported by **Roistacher (1991); Önelge *et al.* (1996).** So, the correlation between climatic factors and gummy bark disease through GIS are being focused on. Two computational approaches *DIVA*-GIS and Maxent attempts were used to identify the habitat of the gummy bark disease distribution. Several dimensions of the climatic, physical, and ecological variables were taken in consideration (**Table 1**). **Ganeshaiah *et al.* (2003)** reported the predictions of potential distribution of the sugarcane woolly aphid. This report could help in developing strategies for monitoring and managing other pests and/or diseases. BIOCLIM annual Min-temperature, Max-temperature and the points distribution of gummy bark disease in Egypt indicated that, gummy bark disease naturally occurs in the low temperature zones range from 11–14°C at winter and from 28-31°C at summer season (**Figure 2**). To ensure the BIOCLIM data, a map for the gummy bark disease distribution all over the Middle East region where registered by **Bové (1995); Önelge *et al.* (1996); Bernad *et al.* (2005); Mohamed *et al.* (2009); Sofy *et al.* (2010).** Following are the locations mapped: in Iraq (Dora and Al Mansuriya), Oman (Muscat, Salalah and Tanuf), Saudi Arabia (Turabah, Najran and Bishah), Syria (Al Ladhqiyah and Ugarit), Sudan (Kassala, Atbara, Nyala and Zalingei), Pakistan (Tarnab), United Arab Emirates (Al Hamraniyah), Southern Yemen (Mukayris, Lawdar, Mudiyah, Seiyun and Tarim), Northern Yemen (Marib and Harib), Turkey (Dörtyol, Adana, Erzin, Mersin, Alata, Antalya, Köyceğiz and Yeşilkent) as well as Egypt (Kalyobiya and Fayoum). Previous data shows, BIOCLIM annual Min-temperature, Max-Temperature and the points distribution of the gummy bark disease in the Middle East region occurs naturally in the low temperature zones range from

8–18°C at winter and from 27-38°C at summer season where the altitude ranged from -351 to 1320 m according to **Nelson *et al.* (1997).**

Ecological niche modeling has been used to predict current and future species distributions, and to provide recommendations of habitat conservation **(Graham *et al.* 2004)**. Such models can correlate species-presence data with environmental variables i.e. temperature, precipitation, and elevation. **Beaumont and Hughes (2002)** has used for models comparing current and future distributions of Australian butterflies and also to identify species most vulnerable to climate change. Similarly, **Berry *et al.* (2002)** has explored the impacts of climate change on 54 species and 15 habitats in the United Kingdom using a niche modeling technique. These models have been used to identify habitats of climate change, and prediction of butterfly, *Erebia epiphron* Knoch.

MAXENT, a machine-learning method based on the principle of maximum entropy, are used to predict distribution for each species of butterfly under current and future climates. Data from this model is used to test the efficiency of the modeling program through the evaluation of the area under the Receiving Operator Curve (AUC) **(Elith *et al.*, 2006; Phillips *et al.* 2004; 2006)**. MAXENT was used, here in, to create gummy bark disease distribution models. Model was made with both 1950-2000 averaged bioclimatic data.). The Maxent model predicted potential suitable habitat for gummy bark disease distribution in Egypt with high success rates of AUC (0.999) which measures the accuracy of distribution models. The Maxent model's internal jackknife test of variable importance showed that altitude and mean temperature of driest quarter were the two most important factors in prediction of citrus gummy bark disease habitat distribution **(Hijmans *et al.*, 2005)**. This study provides the first predicted potential habitat distribution map for citrus gummy bark disease in Egypt. The potential habitat distribution map for citrus gummy bark disease can help in A) planning management around its existing disease, B) identify top-priority survey sites, or set priorities to restore its natural habitat for more effective conservation. More research is needed to determine whether the existing protected areas adequately cover suitable habitat for citrus gummy bark disease. The methodology presented here in could be used for quantifying habitat distribution patterns for other threatened and endangered plant pathogens and/or plant pests **(Kumar and Stohlgren, 2009)**.

REFERENCES

Beaumont, L.J. and Hughes, L. (2002). Potential changes in the distributions of latitudinally restricted Australian butterfly species in response to climate change. *Global Change Biology* **8**: 954-971.

Bernad, L., Moreno, P., Bové, J.M., and Duran-Vila N. (2005). Viroids in gummy bark sources from the Sultanate of Oman. In *Proc. 16th Conf. IOCV*, p. 272-279. Riverside, IOCV.

Berry, P.M., Dawson, T.P., Harrison, P.A., and Pearson, R.G. (2002). Modelling potential impacts of climate change on the BIOCLIMatic envelope of species in Britain and Ireland. *Gloabal Ecology and Biogeography* **11**: 453-462.

Bové, J.M. (1995). Virus and virus-like disease of citrus in the Near East region. FAO eds, Rome: 518p.

Çinar A., Kersting, U., Onelge, N., Korkmaz, S., and sag, G. (1993). Citrus virus and virus-like diseases in the Eastern Mediterranean region Turkey. In: *Proc. 12th Conf. IOCV.*, p. 397-401. Riverside, IOCV.

El-Dougdoug, Kh.A., Awad, M.A., Shalaby, A.A., Abo-Zeid, A.A. (1997). Viroids infect Mandarin and Navel orange in Egypt. *Arab Universities Journal of Agricultural Sciences* **5**: 209-225.

El-Dougdoug, Kh.A., El-Deeb, S.H., and Abou-Zeid, A.A., (1993). Anatomical and ultrastructural changes in orange leaves infected with *Citrus exocortis viroid* (CEVd). *Annals Agric. Sci.*, Ain Shams Univ., Cairo, **38**: 101-117.

El-Dougdoug, Kh.A., Ghazal, S.A., Mousa, A.A., Fahmy, H., and Sofy, A.R. (2009). Differentiation among three Egyptian isolates of *Citrus psorosis virus*. *International*

Journal of Virology 5(2): 49-63.

Elith, J., Graham, C.H., Anderson, R.P., Dudı´k, M., Ferrier, S., Guisan, A., Hijmans, R.J., Huettmann, F., Leathwick, J.R., Lehmann, A., Li, J., Lohmann, L.G., Loiselle, B.A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J. McC., Peterson, A.T., Phillips, S.J., Richardson, K.S., Scachetti-Pereira, R., Schapire, R.E., Sobero´n, J., Williams, S., Wisz, M.S. and Zimmermann, N.E. (2006). Novel methods improve prediction of species distributions from occurrence data. *Ecography* **29**:129-151.

Ganeshaiah, K.N., Barve, N., Nath, N., Chandrashekara, K., Swamy, M., and Uma Shaanker R. (2003). Predicting the potential geographical distribution of the sugarcane woolly aphid using GARP and *DIVA*-GIS. *CURRENT SCIENCE* **85(11)**:1526-1528.

Graham, C.H., Ron, S.R., Santos, J.C., Schneider, C.J., and Moritz, C. (2004). Integrating phylogenetics and environmental niche models to explore speciation mechanisms in dendrobatid frogs. *Evolution,* **58(8),** 1781–1793.

Grinnell, J. (1924). Geography and evolution. *Ecology* **5**: 225-229.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., and Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* **25**: 1965-1978.

Intergovernmental Panel on Climate Change (IPCC) (2001). Sep. 24. Summary for policymakers. <http://www.ipcc.ch/pub/un/syreng/spm.pdf>. Accessed 2006 Apr. 15.

Kumar, S., and Stohlgren, T.J. (2009). Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and Natural Environment* **1(4)**: 094-098.

Mohamed, M.E., Bani Hashemian, S.M., Dafalla, G., Bové, J.M., and Duran-Vila, N. (2009). Occurrence and identification of citrus viroids from Sudan. *Journal of Plant Pathology* **91(1)**: 185-190.

Nelson, A., LeClerc, G., and Grum, M. (1997). The development of an integrated Tcl/Tk and C interface to determine, visualize and interrogate infraspecifc biodiversity. Internal CIAT document. GIS Laboratory, CIAT, Cali, Colombia.

Nour-Eldin, F. (1956). Phloem discoloration of sweet orange. *Phytopathology* **46**: 238-239.

Nour-Eldin, F. (1959). Citrus virus disease research in Egypt. In *J.M.* Wallace, ed. *Citrus virus diseases, p.* 219-227. Berkeley, Div. Agric. Sci., Univ. Calif.

Önelge, N., Cinar, A., Kersting, U., and Semancik, J.S. (1996). Viroids associated with citrus gummy bark disease of sweet orange in Turkey. Pages 245-248 in: *Proc. 13th. Int. Conf. Organ. Citrus Virol. IOCV*: Riverside, CA.

Önelge, N., Cinar, A., Szychowski, J.A., Vidalakis, G., Semancik, J.S. (2004). Citrus viroid II variants associated with 'Gummy Bark' disease. *European Journal of Plant Pathology* **110**: 1047-1052.

Parmesan, C., and Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, (London) **421**: 37-42.

Phillips, S.J., Anderson, R.P., and Schapire, R.E. (2006). Maximum entropy modeling of species geographic distributions. *Ecol. Modell.* **190**: 231-259.

Phillips, S.J., Dudik, M., and Schapire, R.E. (2004). A maximum entropy approach to species distribution modeling. Proceedings of the 21st International Conference on Machine Learning. ACM Press, New York pp. 655–662.

Roistacher, C.N. (1991). Graft-transmissible Diseases of Citrus. Handbook for Detection and Diagnosis. FAO, Rome, Italy.

Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C., and Pounds, J.A. (2003). Fingerprints of global warming on wild animals and plants. *Nature* (London) **421**: 57 60.

Sofy, A.R., Soliman, A.M., Mousa, A.A., Ghazal, S.A., and El-Dougdoug, Kh.A. (2010). First record of *Citrus viroid II* (CVd-II) associated with gummy bark disease in sweet orange (*Citrus sinensis*) in Egypt. *New Disease Reports,* **21**, 24. [doi:10.5197/j.2044-0588.2010.021.024].