POTENTIAL DISTRIBUTION OF ORANGE JASMINE (*Murraya paniculata*) IN MÉXICO

[DISTRIBUCIÓN POTENCIAL DE LIMONARIA (*Murraya paniculata*) EN MÉXICO]

José López-Collado[1]* and J. Isabel López-Arroyo[2]

*[1]Colegio de Postgraduados, Campus Veracruz.
Km 88.5 Carretera Xalapa-Veracruz. Veracruz.
E-mail: lopez.jose@inifap.gob.mx, jlopez@colpos.mx
[2]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias.
Campo Experimental General Terán. Km. 31 Carretera Montemorelos-China
Ex-Hacienda Las Anacuas. C.P. 67400.
Corresponding author

SUMMARY

Orange jasmine (OJ) is a common ornamental plant used as green hedge in public and private gardens in Mexico. It also hosts Huanglongbing, a worldwide citrus disease and its vector, *Diaphorina citri*. For risk analysis and management purpose is important to know its geographic distribution. The potential distribution of OJ was calculated in Mexico using a deductive approach. Based on temperature and precipitation requirements, a relative suitability index was computed by combining the normalized values of both variables. The distribution was overlapped with captures of *D. citri* to check their spatial similarity. The results showed that the potential of occurrence is high in the Pacific and Gulf of México coastal states, including the Yucatán peninsula, and the lowest values appeared in the north-western states. The OJ distribution overlaps with Huanglongbing occurrence and coincided with captures of *D. citri* for most of the suitable area but *D. citri* captures extended beyond the optimal OJ distribution values in the northern regions of México.

Key words: citrus; asian citrus psyllid; yellow dragon; species distribution modeling.

RESUMEN

La limonaria es una planta ornamental usada comúnmente en setos vivos de jardines tanto públicos como privados en México. También es hospedera del Huanglongbing, una enfermedad de cítricos de distribución mundial y de su vector, *Diaphorina citri*. Para propósitos de análisis de riesgo y manejo, es importante saber su distribución geográfica. El potencial de distribución de limonaria se calculó para México mediante un enfoque deductivo. Con base en los requerimientos de temperatura y precipitación se calculó un índice relativo de aptitud con la combinación de ambas variables normalizadas. La distribución se traslapó con capturas de *D. citri* para ver su similitud espacial. Los resultados indicaron que el potencial de ocurrencia es alto en los estados costeros del Pacífico y Golfo de México, incluyendo la península de Yucatán y los valores más bajos aparecieron en los estados del noroeste. La distribución de limonaria se traslapa con la del Huanglongbing y coincidió con las capturas de *D. citri* para la mayor parte del área disponible pero las capturas de *D. citri* se extendieron más allá de la distribución óptima de limonaria en las regiones del norte de México.

Palabras clave: cítricos; psílido asiático de los cítricos; dragón amarillo; modelado de distribución de especies.

INTRODUCTION

Orange jasmine OJ *Murraya paniculata* (L.) Jack (Rutaceae) is a plant used in parks and gardens for ornamental purposes such as green hedges (Guilman, 1999). However, it hosts *Candidatus* Liberibacter spp. which causes the disease called Huanglongbing

(HLB) (Bové, 2006). OJ also hosts the vector of HLB, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae), the Asian citrus psyllid ACP (da Graça, 1991; Bové and Garnier, 2002; Damsteegt *et al*., 2010). The ACP was first detected in México in 2002 and since then it has spread throughout the country; its presence has been reported in all the citrus-

producing states (López-Arroyo *et al*., 2004, 2009). The HLB is a worldwide disease that attacks various citrus species, it has moved from Asia to the American continent, where is present in Brazil, U.S.A., Central America, Caribbean Islands, and México (National Research Council, 2010). In México, the HLB was introduced in 2009, it occurs in some municipalities of Baja California Sur (BCS), Chiapas (CHP), Campeche (CAM), Colima (COL), Hidalgo (HID), Jalisco (JAL), Michoacán (MIC), Nayarit (NAY), San Luis Potosí (SLP), Sinaloa (SIN), Quintana Roo (ROO) and Yucatán (YUC) (SENASICA, 2012). Although OJ is host of both *D. citri* and HLB (Yang *et al*., 2006), investigations have focused primarily on commercial citrus; few researches have been aimed to study the importance of OJ in HLB and *D. citri* epidemiology. The geographic distribution of *M. paniculata* on Japanese islands has been estimated and is closely related to *D. citri* (Kohno *et al*., 2001). Orange jasmine is a plant classified as type 9B in the USDA hardiness zone categories (Guilman, 1999). The occurrence of *D. citri* populations in OJ shrubs in urban areas poses a risk to adjacent commercial citrus plantations (Hernández-Landa *et al*., 2011). Despite being one of the most preferred host to HLB and *D. citri*, the spatial distribution of OJ in México is unknown.

Estimation of habitat distribution is important for ecological niche estimation, conservation management, risk analysis and pest control (Cayuela *et al*., 2009; Franklin, 2009; Venette *et al*., 2010). Habitat or niche distribution is estimated by means of inductive, deductive and hybrid methods (Venette *et al*., 2010). Inductive methods rely on actual point data, collected through direct sampling or by analyzing data obtained from specimens stored in museums (Elith and Leathwick, 2009). Deductive methods use bioclimatic requirements such as temperature and precipitation to compute such distribution (Kearney and Porter, 2009; Buckley *et al*., 2010); hybrid techniques make use of both methods (Franklin, 2009). Because *D. citri* and HLB are already in México, it is important to know where OJ plants can be located, thus the objective of this study was to determine the potential distribution of this species in México.

MATERIAL AND METHODS

The work used a deductive approach to compute the potential habitat distribution. Two bioclimatic variables were used as predictor variables, temperature of coldest month (Temp, °C) to account for the assumption that extreme low temperatures constrain plant distribution (McKenney *et al*., 2007; Magarey *et al*., 2008), and mean annual precipitation (Ppt, mm) that is required for the plant to grow (Guilman, 1999; Francis, 2010). The variables were

combined into a relative suitability index (RI) in a two-step procedure. In the first step each bioclimatic variable Vj (j= 1, 2; V_1 = Temp, V_2 = Ppt) was transformed by applying the equation: $Nij = (Vij-Vminj)/(Vmaxj-Vminj)$, where Nij is the normalized value, between 0 and 1, obtained from the environmental variable Vj; Vmaxj and Vminj are the minimum and maximum values respectively (Teknomo, 2011) subject to the constrains that $V_1 > -4.0$ °C and $V_2 > 750$ mm, otherwise Vij = 0 (Guilman, 1999; Francis, 2010). After determining the normalized values, the second step consisted of calculating RI as a simple average:

$$RI_i = \frac{\sum_j Nij}{n}.$$

The RI values were plotted on a map using a color scale with ArcGIS 9.3.1 (ESRI, 2009). Temperature and precipitation raster layers were obtained from Fernandez-Eguiarte *et al*. (2010); these layers were curated from the WorldClim database, derived from historic global source data ranging from 1950 to 2000 and have a spatial resolution of 30" or about 0.86 km^2 at the Equator; the layers were generated by interpolation with a thin-plate smoothing spline algorithm (Hijmans *et al*., 2005). Map algebra operations (Tomlin, 1991) were performed with Octave 3.2 (Eaton *et al*., 2008). To complement the analysis, the RI map included a sample of a 1000 georeferenced point data of *D. citri* captures made during 2008 and 2009 by SENASICA personnel in different parts of the Mexican Republic; details of *D. citri* sampling are described by Robles-Garcia and Delgadillo-Villanueva (2008).

RESULTS AND DISCUSSION

The potential distribution, estimated by RI, is presented in the map showed in Figure 1. It is observed that the best conditions for occurrence appear from the south of Sinaloa to Chiapas in the Pacific coast, most of the Gulf of Mexico coastal states excluding Tamaulipas (TAM), and the entire Yucatán Peninsula region (CAM, ROO, YUC). Conversely, the central states are less appropriate while the northwestern states have the lowest suitability values, revealing a restricted habitat potential in parts of Baja California Norte (BCN), Chihuahua (CHH), Durango (DUR) and the northeastern part of Sonora (SON), where RI have values near or equal to zero. Orange jasmine high-suitability areas like those presented in Chiapas, Colima, Jalisco, Michoacán, Nayarit, And Yucatán Peninsula, coincide with the occurrence of *D. citri* and HLB as well (SENASICA, 2012). States where HLB is present and have low to medium RI values are

Hidalgo, San Luis Potosí and Sinaloa (SENASICA, 2012). The highest OJ distribution values overlap with *D. citri* counts but the insect extends its presence to the northern states, like Baja California Norte and Sur, Nuevo Leon (NLE), Sonora and Tamaulipas; probably because it feeds on other hosts and has different bioclimatic requirements. For example, the lower threshold temperature for *D. citri* is about 12 °C (Nava *et al*., 2010). These northern states also have commercial citrus production, thus providing a primary host to *D. citri* (SIAP, 2010). Interestingly, appropriate OJ sites extend to southern Florida and Cuba, places where again, orange jasmine, HLB and *D. citri* occurs (Tsai *et al*., 2000, 2002; Manjunath *et al*., 2008). The OJ distribution in southern states of USA visually coincided with the map reported by Gilman (1999), thus providing a partial, independent validation of this model.

The estimated distribution should be considered as approximate because OJ is a garden plant; management activities may modify its bioclimatic requirements and thus its distribution (McKenney *et al*., 2007; Franklin, 2009). For example, the constraint on precipitation could be relaxed if the plants are subject to irrigation, as usual for garden plants. Other factors may affect its distribution as well; it is known that soil type also affect their development, OJ is tolerant to alkaline, clay, sandy, acidic and calcareous soils (Guilman, 1999). Validation of this model would require comparing the predicted values with actual records of individual's presence. Thus, further studies are needed to validate or better estimate the habitat distribution of this species; possibly analyzing actual occurrence data along with predictor variables using inductive methods, such as maximum entropy (Phillips *et al*., 2006), genetic algorithms (Stockwell and Peters, 1999), or ecological niche factor analysis (Hirzel *et al*., 2002). Another approach is to build a more comprehensive deductive mechanistic model, based on physiological relationships between development and abiotic variables (Buckley *et al*., 2010) such as those constructed for poikilothermic organisms like insects (Kearney *et al*., 2009); however this approach requires data obtained from controlled experiments at varying temperatures (Kurtyka *et al*., 2011).
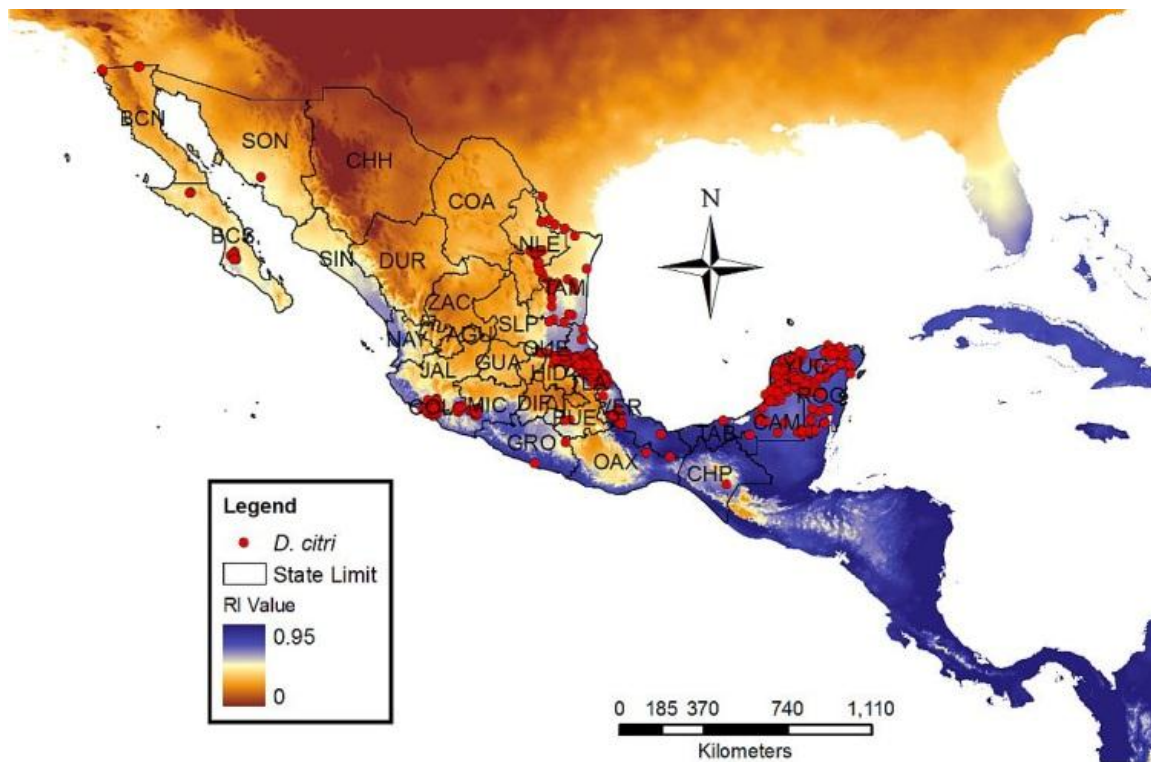

Figure 1. Distribution of the Relative Suitability Index (RI) of orange jasmine in México. The points (•) indicate *D. citri* capture sites. Full state names are described in text.

Despite using a simple method to estimate the OJ distribution, the overlap of *D. citri* captures with optimal suitability index values along with the presence of HLB in some of the study regions mean that management of HLB and its vector should take into account the occurrence of OJ plants. In fact, it has been showed that *D. citri* populations fluctuate in OJ shrubs within urban areas, thus representing a risk as a vector source near commercial citrus plantations (Hernández-Landa *et al.*, 2011). In most cases, OJ is restricted to urban areas as a garden plant (Guilman, 1999); however, OJ seeds can be dispersed by birds (White *et al.*, 2006) and leafcutter ants (Pickard *et al.*, 2011) and thus may become a weed in riparian rainforest areas (White *et al.*, 2006); as such, the plant has been ranked as a minor invasive weed (Downey *et al.*, 2010). Overall, OJ poses several challenges such as to find out what role it plays in hosting HLB and *D. citri* populations and what risk imposes to commercial citrus fields located near urban areas and to citrus packing warehouses.

CONCLUSIONS

The most suitable distribution areas of *M. paniculata* in Mexico ranged from the south of Sinaloa to Chiapas in the Pacific coast, most of the Gulf of Mexico coastal states excluding Tamaulipas, and the whole Yucatán Peninsula. Northern and central states had lower distribution values, being Chihuahua and Durango the less suitable. The distribution of *M. paniculata* overlapped with HLB occurrence and with counts of *D. citri* but the insect extended its presence to northern states. Further studies are required to validate or improve the habitat distribution of *M. paniculata* in México.

ACKNOWLEDGEMENTS

REFERENCES

Bové, J.M. 2006. Huanglongbing: A destructive, newly-emerging, century-old disease of citrus. Journal of Plant Pathology. 88: 7-37.

Bové, J.M., Garnier, M. 2002. Phloem-and xylem-restricted plant pathogenic bacteria. Plant Science. 163: 1083-1098.

Buckley, L.B., Urban, M.C., Angilletta, M.J., Crozier, L.G., Rissler, L.J., Sears, M.W. 2010. Can mechanism inform species´ distribution models? Ecology Letters. 13: 1041-1054.

Cayuela, L., Golicher, D.J., Newton, A.C., de Alburquerque, F.S., Arets, E.J.M.M., Alkemade, J.R.M., Pérez, A.M. 2009. Species distribution modeling in the tropics: problems, potentialities, and the role of biological data for effective species conservation. Tropical Conservation Science. 2: 319-352.

da Graça, J.V. 1991. Citrus greening disease. Annual Review of Phytopathology. 29: 109-136.

Damsteegt, V.D., Postnikova, E.N., Stone, Kulhman, M., Wilson, C., A.L.,Sechler, A., Schaad, N.W., Brlansky, R.H., Schneider, W.L. 2010. *Murraya paniculata* and related species as potential hosts and inoculum reservoirs of 'Candidatus Liberibacter asiaticus', causal agent of Huanglongbing. Plant Disease. 94: 528-533.

Downey, P.O., Scanlon, T.J., Hosking, J.R. 2010. Prioritizing weed species based on their threat and ability to impact on biodiversity: a case study from New South Wales. Plant Protection Quarterly. 25(3): 111-126.

Eaton, J.W., Bateman, D., Haugber, S. 2008. GNU Octave. A High-Level Interactive Language for Numerical Computations. 3rd. Edition. Network Theory Limited. United Kingdom. 618 pp.

Elith, J., Leathwick, J.R. 2009. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution, and Systematics. 40: 677-697.

ESRI, 2009. ARCGIS 9.3.1. Redlands, California. U.S.A.

Fernández-Eguiarte, A., Zavala-Hidalgo, J., Romero-Centeno, R. 2010. Atlas Climático Digital de México. Centro de Ciencias de la Atmósfera. UNAM. On line: http://atlasclimatico.unam.mx/atlas/kml/. Accessed: August 1, 2010.

Francis, J.K. 2010. *Murraya exotica*. http://www.fs.fed.us/global/iitf/pdf/shrubs/Murraya%20exotica.pdf. Accessed: December 10, 2010.

Franklin, J. 2009. Mapping Species Distribution. Spatial Inference and Prediction. Cambridge University Press. New York. 320 pp.

Guilman, E.F. 1999. *Murraya paniculata*. University of Florida. Cooperative Extension Service. Fact Sheet FFPS-416. Gainesville, Fla. U.S.A. 3 pp.

Hernández-Landa, L., López-Collado, J., García-García, C.G., Osorio-Acosta, F., Nava-Tablada, M.E. 2011. Dinámica espacio-temporal de *Diaphorina citri* en limonaria (*Murraya paniculata*) en Cuitláhuac, Veracruz. *In*: XXIV Científica-Tecnológica Forestal y Agropecuaria Veracruz y III del Trópico Mexicano. Xalapa, Veracruz. México.

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

Hirzel, A.H., Hausser, J., Chessel, D., Perrin, N. 2002. Ecological-niche factor analysis: how to compute habitat-suitability maps without absence data. Ecology. 83: 2027-2036.

Kearney, M., Porter, W. 2009. Mechanistic niche modeling: combining physiological and spatial data to predict species. Ecology Letters. 12: 1-7.

Kearney, M., Porter, W.P., Williams, C., Ritchie, S., Hoffman, A.A. 2009. Integrating biophysical models and evolutionary theory to predict climatic impacts on species´ ranges: the dengue mosquito *Aedes aegypti* in Australia. Functional Ecology. 23: 528-538.

Kurtyka R., Burdach, Z., Karcz, W. 2011. Temperature dependence of growth in maize seedlings and excised coleoptile segments. Polish Journal of Environmental Studies. 20(5): 1221-1225.

López-Arroyo, J.I., Peña, M.A., Rocha Peña, M.A., Loera, J. 2004. Occurrence of the asiaticus citrus psyllid, *Diaphorina citri* (Homoptera: Psyllidae) in México. *In*: Proceedings of the XVI Conference of the International Organization of Citrus Virologists. November 7-13, 2004. Monterrey, N.L. México. p. 179.

López-Arroyo, J.I., Jasso, J., Reyes, M.A., Loera-Gallardo, J., Cortez-Mondaca, E., Miranda, M.A. 2009. Perspectives for biological control of *Diaphorina citri* (Hemiptera: Psyllidae) in Mexico. *In*: Gottwald T.R., Graham J.H., Editors. Proceedings of the

International Research Conference on Huanglongbing. Dec. 1-5, 2008. Orlando, Florida. U.S.A. pp. 329-330.

Kohno, K., Takahashi, K., Nakata, T., Konishi, K., Yasuda, K., Yoshimatsu, S. 2001. The relationship between the distribution of citrus psylla, the vector insect of citrus greening disease, and the distribution of jasmine orange. JIRCAS Research Highlights. http://150.26.201.12/english/publication/high lights/2001/2001_21.html. Accessed: June 10, 2011.

Magarey, R., Borchert, D.M., Schegel, J.W. 2008. Global plant hardiness zones for phytosanitary risk analysis. Scientia Agricola. 65: 54-59.

Manjunath, K.L., Halbert, S.E., Ramadugu, C., Webbs, S., Lee, R.F. 2008. Detection of ´Candidatus Liberibacter asiaticus´ in *Diaphorina citri* and its importance in the management of citrus huanglongbing in Florida. Phytopathology. 98: 387-396.

McKenney, D.W., Pedlar, J.H., Lawrence, K., Campbell, K., Hutchison, M.F. 2007. Beyond traditional hardiness zones: Using climate envelopes to map plant range limits. Bioscience. 57: 929-937.

National Research Council. 2010. Strategic Planning for the Florida Citrus Industry: Addressing Citrus Greening Disease. The National Academies Press. Washington, D.C. U.S.A. 328 pp.

Nava, D.E., Gomez-Torres, M.L., Rodrígues, M.D., Bento, J.M.S., Haddad, M.L., Parra, J.R.P. 2010. Biology of *Diaphorina citri* (Hem., Psyllidae) on different hosts and at different temperatures. Journal of Applied Entomology. 131:709-715.

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

Pickard, T.G., Souza, G.K., Serrao, J.E., Zanuncio, J.C. 2011. Leafcutter ants: a small dispersal agent of the invasive plant *Murraya paniculata*. Weed Research. 51: 548-551.

Robles-García P., Delgadillo-Villanueva, I. 2008. Protocolo de actuación para la detección del Huanglongbing. SAGARPA-SENASICA.

Dirección de Protección Fitosanitaria. México, D.F. 39 pp.

SENASICA. 2012. Comunicaciones, notificaciones y noticias sobre HLB y su vector. http://www.senasica.gob.mx/?id=2505. Accessed: September 27, 2012.

SIAP. 2010. Cierre de la producción agrícola por estado. Available online, http://www.siap.sagarpa.gob.mx/index.php?option=com_wrapper&view=wrapper&Itemid=351. Accessed: December 15, 2010.

Stockwell, D.R.B., Peters, D. 1999. The GARP modeling system: problems and solutions to automated spatial prediction. International Journal of Geographic Information Science. 13: 143-158.

Teknomo, K. 2011. Normalization. http://people.revoledu.com/kardi/tutorial/Similarity/Normalization.html. Accessed: June 20, 2011.

Tomlin, C.D. 1991. Cartographic modelling. *In*: Maguire D.J., Goodchild, M.F., Rhind, D.W. (eds.). Geographic Information Systems. Vol. 1, Chapter 23. Longman, England. pp: 361-374.

Tsai, J.H., Wang, J., Liu, Y. 2000. Sampling of *Diaphorina citri* (Homoptera: Psyllidae) on orange jessamine in southern Florida. Florida Entomologist. 83: 446-459.

Tsai, J.H., Wang, J., Liu, Y. 2002. Seasonal abundance of the asian citrus psyllid, *Diaphorina citri* (Homoptera: Psyllidae) in southern Florida. Florida Entomologist. 85: 446-451.

Venette, R.C., Kriticos, D.J., Magarey, R.D., Koch, F.H., Baker, R.H.A., Worner, S.P., Gómez, N.N.R., McKenney, D.W., Dobesberger, E.J., Yemshanov, D., De Barro, P.J., Hutchison, W.D., Fowler, G., Kalaris, T.M., Pedlar, J. 2010. Pest risk maps for invasive alien species: A roadmap for improvement. Bioscience. 60: 349-362.

White, E., Vivian-Smith, G., Gosper, C.R. 2006. *Murraya paniculata*: what is the potential for this popular ornamental plant to become an environmental weed? *In*: Fifteenth Australian Weeds Conference. pp. 63-66. Available online, http://www.caws.org.au/awc/ 2006/awc200610631.pdf. Accessed: December 1, 2011.

Yang, Y., Huang, M., Beattie, G.A.C., Xia, Y., Ouyang, G., Xiong, J. 2006. Distribution, biology, ecology and control of the psyllid *Diaphorina citri* Kuwayama, a major pest of citrus: A status report for China. International Journal of Pest Management. 52: 343-353.