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; V1 = Temp, V2 = 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 constraints that V1 > -4.0 °C and V2 > 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:

\[
RI_i = \frac{\sum N_{ij}}{n}
\]

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-Eguia 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 km² 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 Potosi 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 (Gilman, 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.

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**REFERENCES**


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