AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Broadleaf weeds associated with the cultivation of habanero chili (*Capsicum chinensis*) in the Yucatan Peninsula, Mexico

Lomas-Barrie, Claudia T.; Loeza-Kuk, Emiliano; Rangel-Fajardo, María A.*

Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Centro de Investigación Regional Sureste (CIRSE), Campo Experimental Mocochá, Antigua Carretera Mérida-Motul km 25, Mocochá, Yucatán, México, C. P. 97454.

* Correspondence: rangel.alma@inifap.gob.mx

ABSTRACT

Objective: To identify the weeds associated with habanero chili cultivation in the Yucatan Peninsula that can be considered pest hosts.

Design/Methodology/Approach: Composite soil samples were obtained from plots established with habanero chili in the states of Campeche, Yucatán, and Quintana Roo. The samples were taken to a greenhouse, where the weeds emerged and developed. The weeds were identified through images and with the support of herbariums. Indeces were used to identify the state with the greatest floristic diversity. DNA from symptomatic plants was obtained to confirm the presence of begomovirus.

Results: The Asteraceae family stood out among the 31 weed families that were identified. The floristic composition was different in the three states. The dominant species were *Amaranthus spinosus*, *Parthenium hysterophorus*, and *Acmella oppositifolia* in Campeche, Yucatán, and Quintana Roo, respectively. The state with the greatest diversity and richness was Yucatán. Twenty-six out of the thirty-one symptomatic samples tested positive for begomovirus.

Limitations/Implications: The seed banks have constant variations from one cycle to another; consequently, it is not possible to obtain the total of the species present in the samples.

Conclusions: It is necessary to establish the weed species present to propose improvements in technological packages and achieve sustainable management.

Keywords: seed bank, sustainable management, floristic diversity.

Citation: Lomas-Barrie, C. T., Loeza-Kuk, E., & Rangel-Fajardo, M. A. (2022). Broadleaf weeds associated with the cultivation of habanero chili (Capsicum chinensis) in the Yucatan Peninsula, Mexico. *Agro Productividad*. https://doi.org/ 10.32854/agrop.v15i4.2124

Academic Editors: Jorge Cadena Iñiguez and Libia Iris Trejo Téllez

Received: September 19, 2021.
Accepted: March 18, 2022.
Published on-line: May 9, 2022.

Agro Productividad, 15(4). April. 2022. pp: 51-59.

INTRODUCTION

The habanero chili cultivation is economically important in the Yucatan Peninsula. In 2020, the national production surpassed 21,973.81 tons, 22% of which were produced there (SIAP, 2021). In 2010, the Yucatan Peninsula was awarded the habanero chili denomination of origin in the Diario Oficial de la Federación (DOF 06/04/2010), which decisively boosted the cultivation of this crop.

Image by David Mark at Pixabay

In the study region, this crop is still grown in the open field; this situation implies some disadvantages in terms of the presence of pests and diseases, although some producers are changing to protected agriculture conditions. A frequent problem is the presence of weeds —which become reservoirs of pests and diseases, including the whitefly (*Bemisia tabaci* Genadius) species complex and begomoviruses (Jiang *et al.*, 2004)— and the competition for nutrients, water, and light which reduces the productive potential of the crops (Zita-Padilla, 2008). In some studies about weeds, up to 50% productivity losses have been reported (Cotero, 1997). Other authors report total losses as a result of the competition between weeds and such crops as cotton, peas, corn, and carrots (Zamorano *et al.*, 2008; Blanco *et al.*, 2014; Cardenal-Rubio *et al.*, 2016). Weeds can cause direct and indirect damages (Liebman *et al.*, 2001). The weeds present in the crops can host disease-transmitting insects and viruses that can infect the habanero chili (Ying and Davis, 2000; Capinera, 2005; Dimeska *et al.*, 2011; Orfanidou *et al.*, 2016).

Studying seed banks is a tool to carry out an efficient control of pests and avoid the crop-weeds competition (Vargas-Gutiérrez and Blanco-Metzler, 2012; Zepeda-Gómez *et al.*, 2015; Caproni *et al.*, 2015; Cardenal-Rubio *et al.*, 2016). Between 70,000 and 90,000 seeds per square meter can be found within the first 15 cm of agricultural soil; this can provide a perspective on the type of weed and the potential control. The time and number of seeds kept in the soil is variable (Shiferaw *et al.*, 2018). The number of weeds present is very similar between the open field and the evaluation of the seed bank carried out in the greenhouse (Ribeiro-Mesquita *et al.*, 2016). Consequently, the objective of this work was to identify the seed bank weeds present in habanero chili fields in the Yucatan Peninsula.

MATERIALS AND METHODS

In order to determine the diversity of weeds present in habanero chili crops, two soil samples were obtained: the first, at the beginning of the 2013 wet season (June and July); the second, during the 2014 dry season (February and March). Both collections were made before the sowing started. Of the five sampling sites, three are located in the municipalities of Othón P. Blanco (Quintana Roo), Tizimín (Yucatán), and Muna (Yucatán) and have a warm subhumid climate with summer rains, with an intermediate humidity regime, and a >10% winter rainfall with regard to the annual total [Aw1(x')]. The other two sites —located in the municipality of Cayal in Campeche (Aw1) and in Mocochá in Yucatán (Aw0)— are less humid and have a warm sub-humid climate with summer rains and winter rains ranging from 5 to 10% of the annual total (García, 1997).

The soil type found in Tizimín and Mocochá is Rendzinas with medium texture, while in Chetumal the soil has a fine texture. In Uxmal the soil is eutric Nitisol with a fine texture; while Cayal has orthic Solonchak type soils with a fine texture (INIFAP-CONABIO, 1995).

The samples were taken in the established 400-m^2 plots, along four X-shaped diagonal transects, starting from the center of the plot and moving towards the edge. Each sample was taken 5 m apart from the previous one, at a 20-cm deep soil extraction point. Each of the nine samples per plot had a 20×20×20 cm volume.

In order to determine the diversity associated with the plots, the soil samples were placed in 53×26×6 cm trays with 1 centimeter of inert substrate and Agrolita™ substrate, under confined conditions in a greenhouse. The seeds were subject to constant irrigation in order to promote the germination and phenological development of the plants; they were transplanted into 250-g bags until the reproductive stage, when they were identified. Images of the adult plant with flower, fruit, and seed were obtained. The photographs of the complete plants were taken with a semi-professional camera (Canon model SX50HS) and a professional camera (Sony SLT-A57). The images of the seeds were obtained with a stereoscope (Carl Zeiss) with an adapted camera (Axiocam ERC).

The images and the *in vivo* plants were used to identify the weeds, consulting the online herbarium databases of national and international institutions such as the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO, http://www.conabio.gob.mx/malezasdemexico/2inicio/paginas/lista-plantas.htm), the Centro de Investigación Científica de Yucatán (CICY, http://www.cicy.mx/sitios/flora%20digital/index.php); the Missouri Botanical Garden (http://www.missouribotanicalgarden.org/gardens-gardening/our-garden/plant-records.aspx), the Instituto de Ecología, A. C. (INECOL, http://www.inecol.edu.mx/inecol/index.php/es/ct-menu-item-1/ct-menu-item-5/herbario), and the Herbario Nacional de México of the Universidad Nacional Autónoma de México (MEXU, http://www.ib.unam.mx/botanica/herbario/).

The number of total specimens per year at each sampling point was obtained, as well as the number of families, genera, and species. Biological indices were calculated to measure the alpha diversity defined by Whitakker (1972), considering that the environments are homogeneous among themselves. The species richness (Formula 1) and Margalef (2) indices were calculated, as well as the Simpson (3) and Shannon-Wiener (4) proportional abundance indices (Moreno, 2001).

Formula (1): Total number of species from the census of the sample by entity.

Formula (2): $D_{Mg} = \frac{S-1}{\ln N}$

Where D_{Mg} is the Margalef index, S is the number of species, and N is the total number of individuals.

Formula (3): $\lambda = \sum p_i^2$

Where λ is the Simpson index and p_i is the proportional abundance of i species, *i.e.*, the number of individuals of the i species divided by the total number of individuals in the sample.

Formula (4): $H' = -\sum p_i \ln p_i$

Where H' is the average degree of uncertainty when forecasting to which species an individual randomly selected from the collection will belong (Shannon-Wiener index): *i.e.*, the abundance, taking into account the importance of each species, with respect to the total number of species in the community.

Symptomatic plants were collected at the sampling sites. DNA was isolated with the modified CTAB protocol (Dellaporta, 1983); while the degenerate AV494/AC1048 primers that flank the viral coat protein were used to determine the presence of begomovirus (Holguín-Peña *et al.*, 2004).

RESULTS AND DISCUSSION

During the two years, 5,583 specimens were obtained from the soil samples; the specimens were classified into 31 families with 69 genera and 91 species. The predominant family was Asteraceae with a total of 16 genera and 1,682 identified specimens. Of the Fabaceae family, 7 genera were identified and 70 specimens were recorded. Nearly 1,200 specimens of the Amaranthaceae family were identified (Figure 1).

In the state of Campeche, the most important family was Amaranthaceae, with 50% of the total identified specimens: two species, *Amaranthus spinosus* L. and *Amaranthus polygonoides* L., stood out with 350 and 186 specimens, respectively. This family has proved to be highly adaptable to the Yucatan Peninsula: 12 *Amaranthus* species have been identified as invasive weeds in the agricultural land of the region (Sánchez-del Pino *et al.*, 2019). Meanwhile, the Asteraceae family was predominant in Yucatan (35% of specimens), followed by the Euphorbiaceae family (20%). The most abundant species of each family were *Parthenium hysterophorus* L. (731 specimens) and *Euphorbia dioica* L. (373 individuals). Finally, the Asteraceace family was predominant in Quintana Roo, with 46% of the specimens: *Acmella oppositifolia* L. (290 specimens) was the most abundant species.

Several authors report that the Asteraceae family is predominant in both annual and perennial agricultural crops (Vargas-Gutiérrez and Blanco-Metzler, 2012; Castillo *et al.*

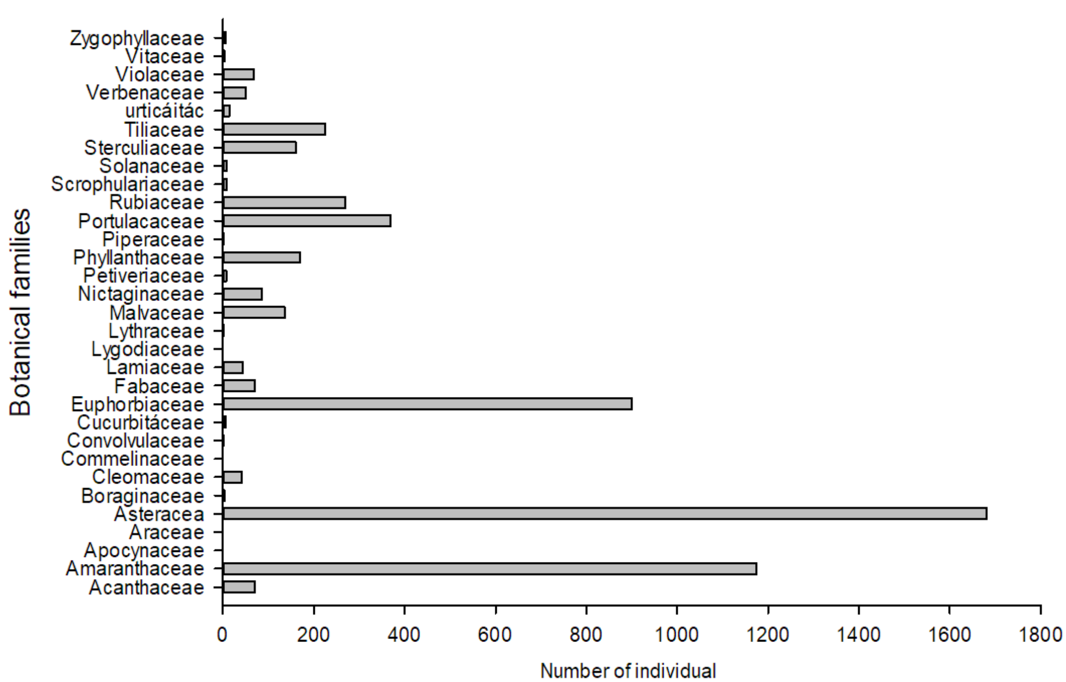

Figure 1. Number of specimens identified per family in the soil samples obtained from habanero chili plots in the Yucatan Peninsula.

2015; Castro-Cepero *et al.*, 2019). Establishing the type of floristic variability within the crop is of the utmost importance, since it will allow an efficient pest control management, as reported by Castillo *et al.* (2015) who identified the entomofauna of the weeds present in various crops, classifying more than 50% as crop pest insects and only 3.79% as parasitoid insects.

The distribution of weeds was heterogeneous in each state: of the total specimens obtained, 3,595 were found in Yucatán, 1,292 in Campeche, and only 696 in Quintana Roo (Figure 2). The previous order was maintained in the values of the biological indices calculated for richness and abundance (Table 1).

Yucatan has a greater richness and abundance than Quintana Roo and Campeche, owing to the higher number of species and the high possibilities of finding them. Even though the soil in the three sampled sites can maintain an active seed bank, the environmental conditions would explain the differences between them. Consequently, although the conditions in Mocochá, Yucatán, are drier (Aw0), the secondary vegetation of the surrounding lowland rain forests compensates for this by being a constant source of diasporas. In contrast, Quintana Roo, despite its humid climate [Aw1(x')], has a physical

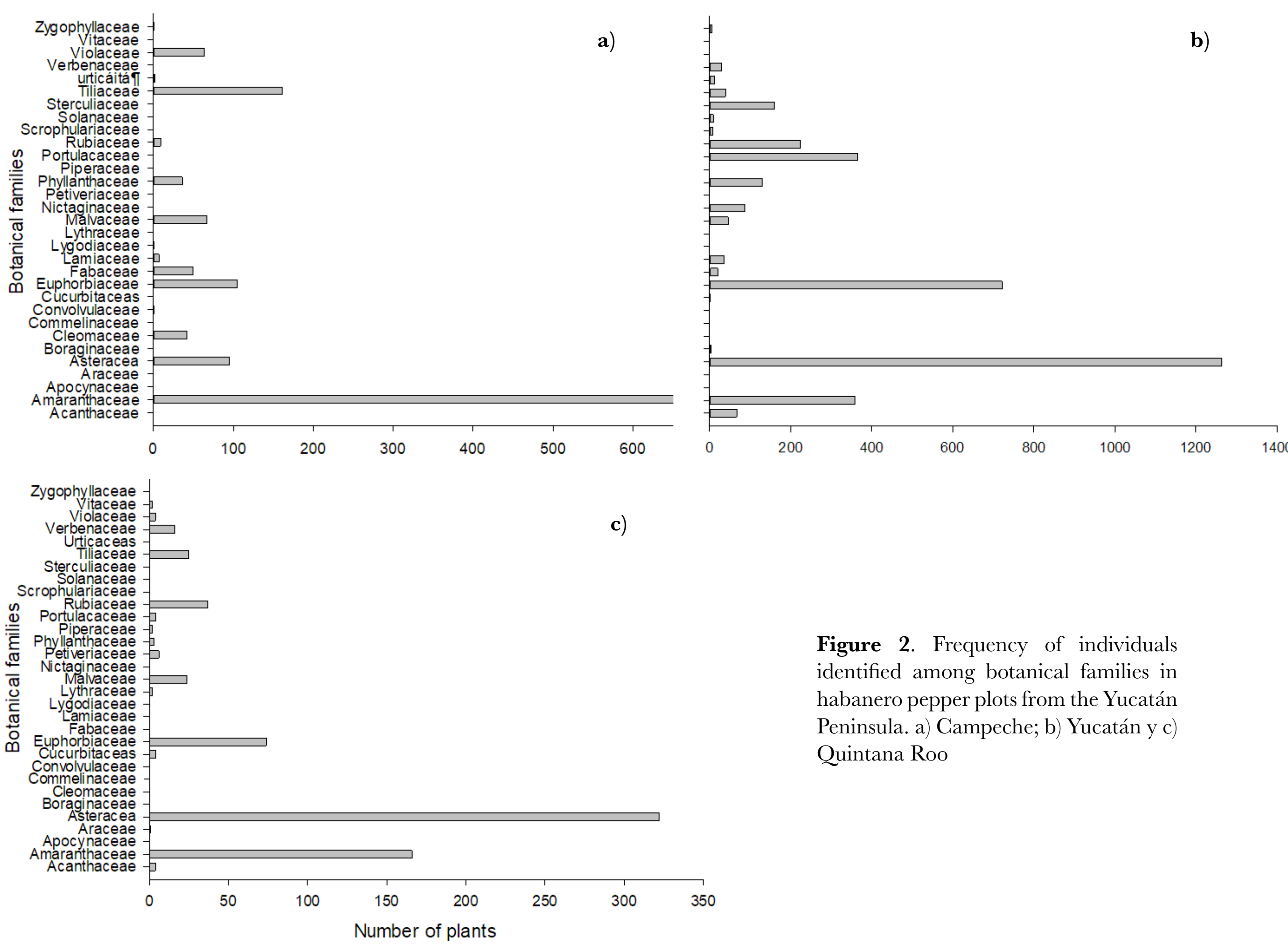

Figure 2. Frequency of individuals identified among botanical families in habanero pepper plots from the Yucatán Peninsula. a) Campeche; b) Yucatán y c) Quintana Roo

Table 1. Alpha diversity biological indicators for each federal entity.

County	Richness		Abundancia	
	R	Dmg	λλ	H'
Campeche	38	5.1648	0.8838	2.6582
Yucatán	73	8.7831	0.9176	2.9828
Quintana Roo	42	6.2544	0.7707	2.1826

R=Specific richness, DMg=Margalef index, λ=Simpson index, H'=Shannon index.

barrier, caused by the planting of *Cedrela odorata* trees which prevent a richer and more abundant seed rain. Even with previous chili sowings and the intensive management of other crops, the low values recorded in Campeche may be the result of the high-water saturation of the Solonchak soil type during the rainy season; this saturation suffocates the reservoir seed bank and therefore the soil only contains newly arrived seeds (Castillo-Argüero *et al.*, 2002; Castellanos-Vargas *et al.*, 2017).

The floristic quantity present in each state was different. The cultivation fields where the soil samples were obtained had significant management differences: the samples from Yucatán and Campeche came from constantly cultivated land, while the crop from Quintana Roo was established on land which had a history of pasture and grazing management and had recently been opened to agricultural management. This can influence the number of families and species present in each sampling, as pointed out by Godoy *et al.* (1995) who indicate that the type of tillage modifies the floristic composition of the weeds that affect the crops by changing the vertical distribution of the seed bank.

The floristic diversity of each region changes according to the season, the year, and the climatic region. Many of these species are highly competitive and prolific, which turns them into reservoirs of both harmful fauna, as well as of beneficial insects (Kumar *et al.*, 2021). Families and species that favor the presence of insect that work as vectors of pathogens have been identified. Of the virus symptomatic plant samples from the seed collection sites, 31 were analyzed and the presence of a begomovirus was confirmed in 26 of them. The genera *Sida* (Malvaceae), *Rhynchosia* (Fabaceae), and *Corchorus* (Tiliaceae) were the most frequent, although specimens from other genera were also infected (Table 2).

Table 2. Weeds with begomovirus incidence in habanero chili (*Capsicum chinense*) cultivation sites.

Family	Genus	Symptoms	Begomovirus (*sensu lato*)
Malvaceae	*Sida* *Anoda* *Whalteria*	+ + +	+ + +
Convolvulacea	*Jacquemontia Merremia*	+ +	+ +
Fabaceae	*Rhinchosia Desmodium*	+ +	+ +
Tiliaceae	*Corchorus*	+	+
Cucurbitaceae	*Melothria*	+	+

The presence of begomoviruses in the weed species analyzed gives a perspective of their function as a source of inoculum for chili crops in these regions. Therefore, these species must be controlled before the crop is established. Begomoviruses transmitted mainly by *Bemisia* have been detected in species of the families Malvaceae, Euphorbiaceae, Asteraceae (Vaca-Vaca *et al*., 2019), Portulaceae, Amaranthaceae, and Tiliaceae (Bezerra *et al*., 2004; Waheed *et al*., 2016). In the study area it is common to find *Sida* sp., *Waltheria*, and *Euphorbia* plants infested by *Bemisia* and infected with begomovirus, although we must highlight that this is not the only insect of economic importance associated with weeds present in crops. Ávila-Alistac *et al*. (2017) report the preference of *Thrips tabaci* for *Ricinus communis* and *Acalypha ostryifolia* species, in the region of Michoacán, Mexico. This report is important because *T. tabaci* is a transmitter vector of the *Iris yellow spot virus* (IYSV). *Frankliniella occidentalis* is another economically relevant thrips, associated as a vector of the tomato spotted wilt virus (TSWV), which occurs more frequently in weeds of the Asteraceae family (Heinz-Castro *et al*., 2012).

Weed families reported as hosts of disease-transmitting insects were identified in the analyzed samples; however, it is necessary to understand the behavior of these insects and their weed-crop relationship (Capinera, 2005), in order to apply a sustainable management of the crop, avoiding excessive application of herbicides and insecticides.

CONCLUSIONS

The floristic diversity present in the cultivation of habanero chili is wide and varied in each state of the Yucatan Peninsula. The diversity present will depend on the cultivation practices, the time the land has been cultivated, the climatic condition, the type of soil, and the condition of the surrounding vegetation. Knowledge about the species present is necessary to propose improvements in technological packages and to allow a sustainable management.

REFERENCES

Ávila- Alistac, N., Ramírez-Rojas, S., Lozoya-Saldaña, H., Rebollar-Alviter, Á., & Guzmán-Plazola, A. R. (2017). Alternate host of *Iris yellow spot virus* and trips on onion crops in Morelos and Michoacan, Mexico. *Revista Mexicana de Fitopatología*, 35(2), 242-262. http://dx.doi.org/10.18781/R.MEX.FIT.1701-1

Bezerra, S. A. M., de Oliveira, V. R. M., & Vasconcelos, D. S. (2004). Does the presence of weeds affect *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) infestation on tomato plants in semi-arid agro-ecosystem? *Neotropical Entomology*, 33(6), 769-775. https://doi.org/10.1590/S1519-566X2004000600015

Blanco, V. Y., Leyva, G. A., & Castro, L. I. (2014). Determinación del periodo crítico de competencia de arvenses en el cultivo de maíz (*Zea mays* L.). *Cultivos Tropicales*, 35(3), 62-69.

Capinera, J. L. (2005). Relationships between insect pests and weeds: an evolutionary perspective. *Weed Science*, 53(6), 892-901. https://doi.org/10.1614/WS-04-049R.1

Caproni, A. L., Stella, S. L., de Oliveira G., J. R. D., Souchi, E. L., Simões P., A. L., Alfaro V., M. A., & Sobanski, E. (2015). Banco de semillas de malezas en sistemas agroforestales. *Global Science and Technology*, 8(2), 28-39. https://doi.org/10.14688/1984-3801/gst.v8n2p28-39

Cardenal-Rubio, Z. C., Torres-Hernández, D. F., Dotor-Robayi, M. Y., & Morillo-Coronado, A. C. (2016). Caracterización del banco de semillas en cultivos de zanahoria del municipio de Villa Pinzón (Cundinamarca). *Revista de la U. D. C. A. Actualidad & Divulgación Científica*, 19(2), 297-306. https://doi.org/10.31910/rudca.v19.n2.2016.83

Castellanos-Vargas, I., García-Calderón, N. & Canon-Santana, Z. (2017). Procesos físicos del suelo en la reserva ecológica del Pedregal de San Ángel de Ciudad Universitaria: atributos para su conservación. *Terra Latinoamericana*, 35(1), 51-64.

Castillo, V. J., Rodríguez, Q. P., Molina, S. P., Cardoso, Z. M., & Vega, R. C. (2015). Entomofauna en las principales malezas asociadas a los cultivos de maíz, cítricos y lúcumo y su población por hectárea en la Molina, Lima, Perú. *Annales Científicos*, 76(2), 315-323. https://doi.org/10.21704/ac.v76i2.796

Castillo-Argüero, S., Guadarrama-Chávez, P., Martínez-Orea, Y., Mendoza-Hernández, P. E., Núñez-Castillo, O., Romero-Romero, M. A., & Sánchez-Gallén, I. (2002). *Diásporas del Pedregal de San Ángel*, 1ª ed.; Prensas de Ciencias-UNAM: Distrito Federal, México. 204 p.

Castro-Cepero, V., Alvarado-Huaman, L., Borjas-Ventura, R., Julca-Ortiniano, A., & Tejada-Soraluz, J. L. (2019). Comunidad de malezas asociadas al cultivo de "café" *Coffea arabica* (Rubiaceae) en la selva central de Perú. *Arnaldoa*, 26(3), 977-990. http://doi.org/10.22497/arnaldoa.263.26308

Cotero, M. A. (1997). *Resistencia de malezas a herbicidas en Colombia*. División de Producción y Protección Vegetal Organización de la Alimentación y la Agricultura de las Naciones Unidas, FAO: Bogotá, Colombia. 7 p.

Dellaporta, S. L., Wood, J., & Hicks, J. B. (1983). A plant DNA minipreparation: version II. *Plant Molecular Biology Reporter*, 1, 19-21. https://doi.org/10.1007/BF02712670

Dimeska, V., Stojkov, S., Krsteska, V., & Gveroska, B. (2011). Weeds as host plants to tobacco diseases and pests. *Tobacco*, 61(1-6), 68-73.

DOF (Diario Oficial de la Federación). (2010). *Declaratoria General de Protección de la Denominación de Origen Chile Habanero de la Península de Yucatán*. 4 de junio de 2010. Recuperado el 8 de marzo de 2022, de DOF: http://dof.gob.mx/nota_detalle.php?codigo=5145315&fecha=04/06/2010

García, E. (1997). *Carta de climas. Escala 1:1000000*. CONABIO/Estadigrafía: Distrito Federal, México.

Godoy, G., Vega, J., & Pitty, A. (1995). El tipo de labranza afecta la flora y distribución vertical del banco de semillas de malezas. *CEIBA*, 36(2), 217-229.

Heinz-Castro, R. T., Thompson-Farfán, R. M., Marín-Sánchez J, Lara-Mireles, J. L., Flores-Dávila, M., & Alcalá-Jáuregui, J. A. (2012). Malezas hospederas de *Frankliniella occidentalis* y reservorios del virus del bronceado del tomate en el Altiplano mexicano. *Fitosanidad*, 17(1), 5-9.

Holguín-Peña, R. J., Vázquez-Juárez, R., Mejía-Ruíz, H., Garzón-Tiznado, J. A., & Rivera-Bustamente, R. F. (2004). Geminivirus en tomate (*Lycopersicon esculentum* Mill) y rango de hospedantes en Baja California Sur, México. *Revista Mexicana de Fitopatología*, 22(1), 107-116.

INIFAP-CONABIO. (1995). *Edafología. Escala 1:250000*. CONABIO: Distrito Federal, México.

Jiang, Y. X., de Blas, C., & Bedford, I. D., Nombela, G., & Muñiz, M. (2004). Short communication. Effect of *Bemisia tabaci* biotype in the transmission of *Tomato Yellow Leaf Curl Sardinia Virus* (TYLCSV-ES) between tomato and common weeds. *Spanish Journal of Agricultural Research*, 2(1), 115-119 http://dx.doi.org/10.5424/sjar/2004021-68

Kumar, S., Bhowmick, K. M., & Ray, P. (2021). Weeds as alternate and alternative hosts of crop pests. *Indian Journal of Weed Science*, 53(1), 14-29. http://doi.org/10.5958/0974-8164.2021.00002.2

Liebman, M., Molher, C., & Staver, C. (2001). *Ecological management of agricultural weeds*, 1st ed.; Cambridge University Press: Cambridge, UK. 544 p.

Moreno, C. (2001). *Métodos para medir la biodiversidad*, 1ª ed.; CYTED, ORCYT-UNESCO y Sociedad Entomológica Aragonesa: Zaragoza, España. 83 p.

Orfanidou, C. G., Pappi, P. G., Efthimiou, K. E., Katis, N. I., & Maliogka, V. I. (2016). Transmission of tomato chlorosis virus (ToCV) by *Bemisia tabaci* biotype Q and evaluation of four weed species as viral sources. *Plant Disease*, 100(10), 2043-2049. http://dx.doi.org/10.1094/PDIS-01-16-0054-RE

Ribeiro-Mesquita, M. L., Alves-Andrade, L., & Pereira, W. E. (2016). Germination, floristic composition and phytosociology of the weed bank in rice interropped with corn fields. *Agrária. Revista Brasileira de Ciências Agrárias*, 11(1), 14-20. http://doi.org/10.5039/agraria.v11i1a5359

Sánchez-del Pino, I., Dorantes-Euan, A., & Ibarra-Morales, A. (2019). Primer registro de la maleza agrícola e invasiva *Amaranthus palmeri* (Amaranthaceae) para la flora de la Península de Yucatán y un registro actualizado de la diversidad de *Amaranthus* en la región. *Botanical Science*, 97(3), 433-446. http://doi.org/10.17129/botsci.2189

Shiferaw, W., Demissew, S., & Bekele, T. (2018). Ecology of soil seed banks: Implications for conservation and restoration of natural vegetation: A review. *International Journal of Biodiversity and Conservation*, 10(10), 380-393.

SIAP (Servicio de Información Agroalimentaria y Pesquera). (2021). *Anuario estadístico de la producción agrícola*. Recuperado el 23 de junio de 2021, de SIAP: https://nube.siap.gob.mx/cierreagricola/

Vaca-Vaca, J. C., Corredor-Sáenz, V. C., Jara-Tejada, F., Betancourt-Andrade, D., & López-López, K. (2019). Nuevos hospederos alternativos de Begomovirus asociados con el cultivo de ají en el Valle del Cauca, Colombia. *Acta Agronómica*, 68(1), 56-60. http://doi.org/10.15446/acag.v68n1.77487

Vargas-Gutiérrez, M., & Blanco-Metzler, H. (2012) Efecto de prácticas de manejo del suelo sobre el banco de semillas de malezas, Guanacaste, Costa Rica. *InterSedes*, 13(26), 45-57.

Waheed, S. A., Lanjar, A. G., Bukero A., Shah, A. R., Nahyoo, S. A., & Chang, B. H. (2016). Weeding, a population suppression tool for *Bemisia tabaco* (Hemiptera: Aleyrodidae) on tomato crop. *Science International*, 28(4), 4007-4012.

Whittaker, R. H. (1972). Evolution and measurement of species diversity. *Taxon*, 21(2/3), 213-251. http://doi.org/10.2307/1218190

Ying, Z., & Davis, M. (2000). Partial characterization and host range of tomato yellow leaf curl virus in south Florida. *Proceedings of the Florida State Horticultural Society*, 113, 185-190.

Zamorano, C., Lopéz, H., & Alzate, G. (2008) Evaluación de la competencia de arvenses en el cultivo de arveja (*Pisum sativum*) in Fusagasugá, Cundinamarca (Colombia). *Agronomía Colombiana*, 26(3), 443-450.

Zepeda-Gómez, C., Lot, A., Antonio-Némiga, X., & Manjarrez, J. (2015). Evaluación del banco de semillas y su importancia en la rehabilitación de la vegetación de humedales del centro México. *Botanical Sciences*, 93(4), 695-707. https://doi.org/10.17129/botsci.245

Zita-Padilla, G. A. (2008). Resistencia de malas hierbas a herbicidas inhibidores de la enzima ACCasa. Tesis doctoral. Universidad de Córdoba, Departamento de Edafología y Química Agrícola. Córdoba, España. 208 p.