Colegio de Postgraduados

Potential zones for the cultivation of *Actinidia chinensis* var. deliciosa in temperate regions of Veracruz, Mexico

López-Páez Fátima K.[1]; Cruz-Castillo Juan G.[2]; Galindo-Tovar María E.[1]; García-Martínez Miguel Á.[1]; Serna-Lagunes Ricardo[1*]

[1] Universidad Veracruzana. Facultad de Ciencias Biológicas y Agropecuarias región Orizaba-Córdoba. Peñuela, Amatlán de Los Reyes S/N, C.P. 94945.
[2] Centro Regional Universitario Oriente. Universidad Autónoma Chapingo. Km 6.2 Carretera Huatusco-Xalapa, Veracruz. México. C.P. 94100.
* Correspondence: rserna@uv.mx

Citation: López-Páez, F. K., Cruz-Castillo, J. G., Galindo-Tovar, M. E., García-Martínez, M. Á., & Serna-Lagunes, R. (2023). Potential zones for the cultivation of *Actinidia chinensis* var. deliciosa in temperate regions of Veracruz, Mexico. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i10.2594

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: June 01, 2023.
Accepted: October 14, 2023.
Published on-line: November 30, 2023.

Agro Productividad, 16(10). October. 2023. pp: 41-48.

ABSTRACT

Objective: to identify potential zones with soil and climate characteristics in municipalities of the state of Veracruz, Mexico for kiwifruit cultivation through modeling.

Design/Methodology/Approach: with the zoning methodology of soil and climate variables and the Kriging projection algorithm of the ArcMap GIS®, the municipalities of the state of Veracruz with soil and climate potential for the cultivation of kiwi adapted to tropical conditions were determined. The Kruskal-Wallis test was used to validate the zoning and determine the similarity of municipalities with soil and climate potential. A cluster analysis was applied to assess the similarity between the variables studied.

Results: the municipalities of Hueyapan de Ocampo, Ixhuatlán del Café, Jalacingo, Magdalena, Mariano Escobedo, Tehuipango and Texhuacán present average soil and climate characteristics for the establishment of kiwi cultivation. Chumatlán and Huatusco presented the greatest soil and climate similarity for the cultivation of this fruit shrub.

Limitations of the study/Implications: this information contributes to the decision-making to establish kiwi by increasing the knowledge of the species. As, up to date, the almost non-existent information has limited the establishment of kiwi cultivation.

Findings/Conclusions: of the total territory of Veracruz 29% shows soil and climate characteristics to introduce kiwi cultivation. Its establishment would represent support for food and socio-economic sovereignty for producers. According to this study, the establishment of kiwi as a crop is viable in various geographical points of Veracruz.

Keywords: *Actinidia chinensis*, Veracruz, introducing alternative crop, new fruit plants.

INTRODUCTION

In 2021, global agricultural production was estimated at 4,154,467.01 (million USD) [1]. This value contributed to the generation of jobs and food security for approximately 70% of the rural population [2]. In Mexico, in 2022, agricultural, livestock and fishing

production was 297,626,608 tons, of which the state of Veracruz contributed 31,804,750 tons. With this figure, the state of Veracruz occupied the second place among those with the highest production [3]. However, such value is mostly due to intensive crops such as sugarcane (*Saccharum officinarum*), coffee (*Coffea arabica*), lemon (*Citrus*×*limon*), orange (*Citrus*×*sinensis*) and chayote (*Sechium edule*). Intensive crops generate a high rate of deforestation and environmental problems [4]. In this context, it is important to introduce alternative crops that allow the diversification of traditional agricultural systems, promoting land use, profitability, food production, jobs, and economic gains, while focusing on sustainability [5].

Kiwifruit (*Actinidia chinensis* Planch; Ericales: Actinidiaceae), is a crop with wide acceptance in the market due to flavor, high content of ascorbic acid (vitamin C), antioxidants and fiber content [6]. In Mexico, the surface area of kiwifruit cultivation is almost zero, so to supply the domestic demand, this fruit is imported from Chile, USA, Italy, and New Zealand. This causes raising in the cost of kiwifruit to 3-6.5 USD ($60 and $130 MXN pesos) per kg in the national market [7].

Due to the fact that there is already an experimental orchard producing green kiwi (*Actinidia chinensis* var. deliciosa) adapted to tropical high-altitude conditions in Huatusco, Veracruz [8]; it is possible that, based on the soil and climate conditions of that geographical point of the kiwi orchard, the environmental coincidence in other municipalities of the state can be modeled, which would allow the identification of potential areas for the implementation of its cultivation [9].

Soil and climate zoning is a technique for mapping the environmental capacity of a geographical space, which a species can take advantage of [10]. In order to obtain soil and climate zoning, data sources are required on soil and climate characteristics needed for the development of the crop [11]. This makes it possible to identify, among a wide range of climate variables, those with similarity in other regions and to make decisions about the viability of areas to establish a given crop [12].

Therefore, the objective of this study was to identify potential zones with soil and climate characteristics in municipalities of the state of Veracruz, Mexico apt for kiwi cultivation (*A. c.* var. deliciosa).

MATERIALS AND METHODS

The state of Veracruz was selected to identify municipalities with geographic areas with environmental potential for kiwi cultivation. Soil and climate parameters of 112 municipalities in the state of Veracruz were evaluated. To this end, the characteristics of the soil and climate conditions of temperature, dominant soil, land use, mean annual precipitation, altitude and type of climate were collected. These variables were obtained from the INEGI database [13], as well as from climate-environmental reports [08].

In the experimental orchard with kiwi cultivation [Project: Cultivo de kiwi (*Actinidia chinensis*) alternativa para las montañas del estado de Veracruz-México. 23170-C-87, Universidad Autónoma Chapingo], the variables were monitored and recorded daily during the year 2021 and 2022, with an electronic device that has temperature and relative humidity sensors, integrated into a USB device (EXTECH brand datalogger model RHT 10). To determine the soil characteristics of the orchard, a profile analysis was carried out in accordance with NOM-021-RECNAT-2000, AS-01 and AS 09 [14] (Table 1).

With the information on the soil and climate characteristics obtained from the area of the experimental kiwi orchard, the Agroecological Zoning (AEZ) methodology proposed by the FAO [15] was implemented and adjusted, which aims to locate areas with optimal conditions for the cultivation of green kiwifruit. Additionally, the methodological proposal to analyze the agroecological potential of *Moringa oleifera* Lam. for the state of Veracruz [16] was followed; for this, the soil and climate factors that favor the development of kiwi cultivation were used.

In order to elaborate the potential zoning, databases and layers of soil and climate content were developed, and through the plugin Point Sampling Tool in Q-GIS©, the information of each environmental layer was collected for each of the municipalities of the state of Veracruz. Once collected, data were analyzed to select those municipalities that were within the environmental range (ecological valence) that the kiwi plant requires for its establishment. ArcMap® 10.3.1 was used to generate models to identify optimal areas for kiwifruit development [17]. Where the soil and climate layers were subjected to the spatial interpolation procedure by the Kriging method, because the algorithm is related to the best unbiased linear predictor (BULP o MPLI). This reduces the variance of errors in the prediction, making this zoning method more reliable [18].

The criteria for classifying the municipalities were set at high (100-80%), medium (40-79%) and low (1-39%) coincidence within the range of optimal soil and climate conditions in the municipalities of Veracruz, which should be statistically similar to those of the experimental kiwi orchard. To prove that the soil and climate conditions present in the experimental orchard were statistically similar to those predicted by the zoning models, a non-parametric Kruskal-Wallis's analysis of variance [19] and a rank comparison test were performed for each soil and climate variable. Additionally, a principal component analysis was applied to identify the influence of soil and climate variables in the municipalities for kiwi plantation. These analyses were performed at $P<0.05$ of confidence level with InfoStat [20].

Table 1. Soil and climate characteristics of the experimental kiwi orchard in the town of Elotepec, municipality of Huatusco, Veracruz, Mexico.

Coordinates	Latitude 19.187 N; Longitude -97.187 W.
Temperature (°C)	10.75
Climate	Warm-wet
Mean altitude (msnm)	1950
Average annual precipitation (mm)	1800
Agricultural land use (%)	52.18
Dominant soil (%)	Andosol (44.28)
	Luvisol (42.88)
	Leptosol (9.87)

RESULTS AND DISCUSSION

The total area of the state of Veracruz is 71,820 km^2, of which 17,651 ha are dedicated to the agriculture of various crops according to the soil, climate, and environmental conditions. In this context, the zones for the adaptation of kiwifruit to tropical high-altitude conditions was located in 60 municipalities which present soil and climate characteristics similar to those of the experimental orchard (Figure 1).

Soil and climate factors limit or promote the development and production of kiwifruit. Temperature, precipitation, altitude, and soil type are characteristics of physiological importance for kiwi plant development [21]. Since kiwi cultivation requires short winters with moderately low temperatures in spring; without risk of frost and mild summers, a rainfall of between 1300 and 1500 mm, deep soils, and good drainage capacity. All of those coincide with the data reported in Table 2, which describes the average and within range values of soil and climate conditions of the municipalities with characteristics for kiwi cultivation.

The Kruskal-Wallis non-parametric analysis of variance (Table 3) indicated that the areas identified in the zoning models for the establishment of kiwi cultivation were significantly equivalent to those recorded in the experimental orchard in the town of Elotepec, Huatusco, Veracruz. For this reason, it is considered feasible to establish small

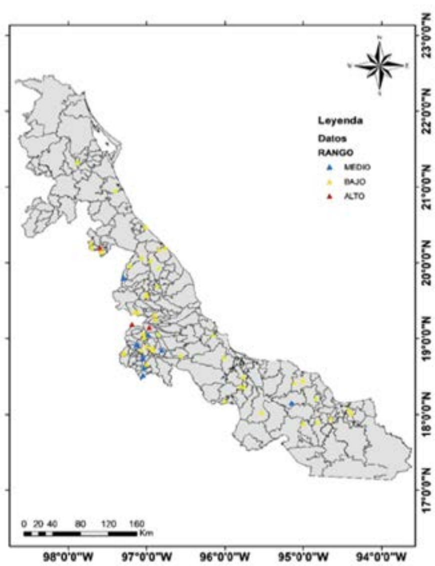

Figure 1. Municipalities with soil and climate conditions for kiwi cultivation.

Table 2. Soil and climate parameters for municipalities with a high percentage of coincidence for the establishment of a kiwifruit crop.

Statisticians	Temperature (°C)	Altitude masl	Precipitation (mm)	Soil type%		
				Andosol	Luvisol	Leptosol
Average	18	1223	1813	29	28	10
Standard deviation	7	768	1047	25	25	0.1
Maximum value	24	1950	1825	44	43	10
Minimum value	11	420	1800	0	0	10

Table 3. Kruskall-Wallis non-parametric analysis of variance to identify the similarity in soil and climate conditions in the selected municipalities with the agroecological zoning, compared to those of the experimental kiwi orchard.

Kruskai wallis in pairs		
Variable	**H**	**P**
Temperature	59.75	0.4757
Altitude	58.87	0.4755
Precipitation	58.54	0.4755
Suitable for agriculture	60.00	0.4757
luvisol soil	51.34	0.4757
Leptosol soil	47.67	0.4757
andosol soil	49.62	0.4757

or backyard plantations in the municipalities indicated, to evaluate the adaptability of the kiwi plant and subsequently evaluate its productivity.

The principal components analysis (Figure 2) indicated that the municipalities with the least variation and higher similarity in soil and climate factors to those of the experimental orchard were Magdalena, Texhuacán, Tehuipango, Huatusco, Ixtaczoquitlán, Sochiapa and Aquila.

Soil and climate conditions have an impact on agricultural productivity. The relationship between a crop and the soil is influenced by various interactions among soil physical and

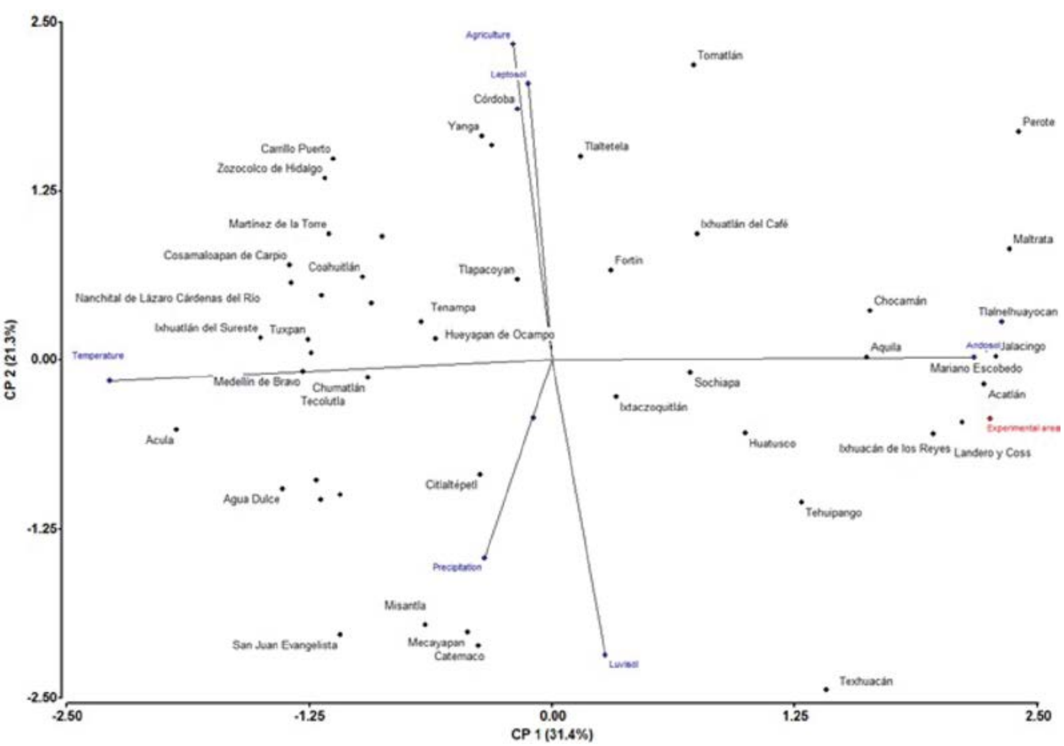

Figure 2. Soil and climate parameters for municipalities with three or more coincidences for the establishment of kiwifruit in Veracruz.

chemical conditions, and external environmental factors [22]. When compared to the soil and climate conditions of the kiwi introduction orchard, 60 municipalities of the state of Veracruz showed soil and climate coincidences. Out of which, 49 municipalities showed a low coincidence percentage; seven a medium percentage (Hueyapan de Ocampo, Ixhuatlán del café, Jalacingo, Magdalena, Mariano Escobedo, Tehuipango and Texhuacán); and two, a high coincidence percentage (Huatusco and Chumatlán) (Figure 3). However, municipalities with less coincidence in conditions can adapt them through agricultural management, such as irrigation, substrates at different concentrations, considering the requirements of the kiwi crop.

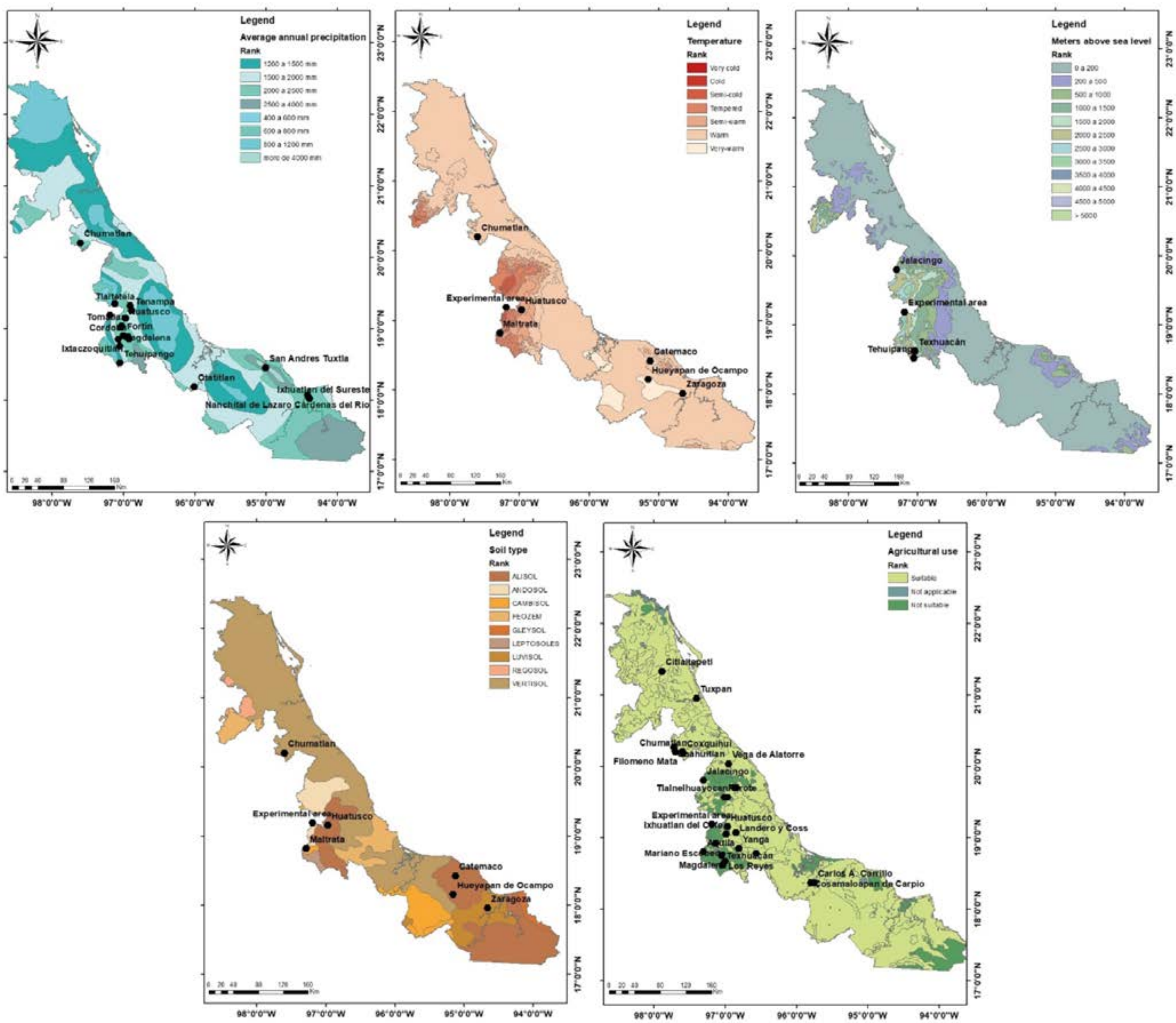

Figure 3. Municipalities of Veracruz (Mexico) with soil and climate aptitude for kiwifruit.

CONCLUSIONS

The municipalities of Veracruz with the greater soil and climate conditions similarity to the experimental orchard were Huatusco and Chumatlán. These municipalities have an average annual temperature of 18 °C, 1813 mm of precipitation and are located at an altitude of 1223 m, with Andosol (29%), Luvisol (28%) and Leptosol (10%) soils available for kiwifruit cultivation.

ACKNOWLEDGEMENTS

To the Mexico's National Council of Science and Technology (CONACyT) for the doctorate scholarship awarded to the first author. To Universidad Veracruzana, Faculty of Biological and Agricultural Sciences for the value of their college education program.

REFERENCES

1. Banco Mundial. Agricultura y desarrollo rural (Consulta 17/02/2023) https://datos.bancomundial.org/tema/agricultura-y-desarrollo-rural
2. FAO (Food And Agriculture Organization Of The United Nations). Food Outlook. Biannual Report on Global Food Markets, 2014. (Consulta: 16/03/2023). https://www.fao.org/documents/card/en/c/fd8798f5-8706-4845-823b-d7b9da9dd181/
3. SIAP (Servicio de Información Agroalimentaria y Pesquera). Expectativas agroalimentarias (Consultado el 06/05/2023) Disponible en https://www.gob.mx/cms/uploads/attachment/file/807700/Expectativas_Febrero_2023.pdf
4. Landeros-Sánchez, C., Moreno-Seceña, J. C., Gavrilov, L. N., Egorova, O. B., & Angón, C. (2011). Impacto de la agricultura sobre la biodiversidad. La biodiversidad en Veracruz: estudio de Estado (Cruz Angón, A., ed.). Comisión Nacional para el Conocimiento de la Biodiversidad, Gobierno del Estado de Veracruz, Universidad Veracruzana, Instituto de Ecología, AC Ciudad de México, México, 477-491.
5. Álvarez Hernández I. J., Díaz Ramos M. A., Sánchez Uranga R., Fernández Viveros J.A., Villegas Narváez J. (2017). Canal De Comercialización De La Malanga Que Se Produce En El Municipio De Actopan y Su Área de Influencia. *Revista Ciencia Administrativa Número Especial*. P 30
6. López-Sobaler, A. M., Aparicio Vizuete, A., & Ortega Anta, R. M. (2016). Beneficios nutricionales y sanitarios asociados al consumo de kiwi. *Nutrición hospitalaria*, 33, 21-25.
7. Cruz Castillo, J. G., Reyna Garcìa, J., Guerra-Ramírez, D., Almaguer Vargas, G., & Castañeda-Vildózola, A. (2022). Producción de kiwi (*Actinidia chinensis*) como contribución a la soberanía alimentaria frutícola de México: Kiwifruit generated in México. *Agro-Divulgación, 2*(4). Recuperado a partir de https://agrodivulgacion-colpos.org/index.php/1agrodivulgacion1/article/view/75
8. Guerra-Ramírez, D., Galicia-Lucas, M., Salgado-Escobar, I., & Cruz-Castillo, J. G. (2021). Características fisicoquímicas y funcionales de la fruta kiwi en una zona tropical de altura en México. *Revista fitotecnia mexicana, 44*(1), 103-103.
9. Mejía, D., Tonon, M. D., & Abad, L. (2018). Distribución potencial del género Polylepis en la Cuenca del río Paute bajo un escenario de cambio climático. *Revista de la facultad de ciencias químicas* (19), 22-37.
10. Aceves-Rangel, L. D., Méndez-González, J., García-Aranda, M. A., & Nájera-Luna, J. A. (2018). Distribución potencial de 20 especies de pinos en México. *Agrociencia, 52*(7), 1043-1057.
11. Quipuscoa-Silvestre, V., Dillon, M. O., Treviño Zevallos, Í., Balvin Aguilar, M., Mejía Rios, A., Ramos Aranibar, D., ... & Montesinos Tubée, D. (2019). Impacto de los cambios climáticos y uso de suelo, en la distribución de las especies de géneros endémicos de Asteraceae de Arequipa. *Arnaldoa, 26*(1), 71-96.
12. Rodríguez-Bautista, G., Segura Ledezma, S. D., Cruz-Izquierdo, S., López-Medina, J., Cruz-Huerta, N., & Valenzuela Nuñez, L. M. (2021). Distribución potencial y caracterización eco-climática de especies silvestres de *Rubus* subgenus *Eubatus* en México. *Polibotánica*, (52), 103-116.
13. INEGI (Instituto Nacional De Estadística Y Geografía). Anuario estadístico y geográfico de Veracruz de Ignacio de la Llave 2017, México, 2017, p. 1-25. (Consulta: 09/10/2023). http://ceieg. veracruz.gob.mx/wp-content/uploads/sites/21/2018/04/AEGEV-2017.pdf.
14. Secretaria De Medio Ambiente y Recursos Naturales (2002). NORMA Oficial Mexicana NOM-021-RECNAT-2000, Que establece las especificaciones de fertilidad, salinidad y clasificación de suelos. Estudios, muestreo y análisis. Diario Oficial de la Federación. http://www.ordenjuridico.gob.mx/Documentos/Federal/wo69255.pdf

15. FAO (Food And Agriculture Organization Of The United Nations). Report on the Agro- Ecological Zones Project. Vol. 1: Methodology and Results for Africa. Food and Agriculture Organization of the United Nations World Soils Report, N 48, Rome, Italia, 1981, p. 158.
16. Carrión Delgado, J. M., Valdés Rodríguez, O. A., Gallardo López, F. & Palacios Wassenaar, O. M. (2022). Potencial agroecológico de *Moringa oleifera* Lam. para el estado de Veracruz. *Revista mexicana de ciencias forestales*, 13, 42-63. https://www.scielo.org.mx/scielo.php?script=s ci_arttext&pid =S2007-11322022000200042
17. ArcGIS ESRI Desktop: Release 10.3.1. Redlands, CA: Environmental Systems Research Institute. 2015
18. Del-Rosario-Arellano, J. L., Aguilar-Rivera, N., Leyva-Ovalle, O. R., Andres-Meza, P., Meneses-Marquez, I., & Bolio-López, G. I. (2022). Zonificación edafoclimática de la yuca (*Manihot esculenta* Crantz) para la producción sostenible de bioproductos. *Revista de Geografía Norte Grande,* (81), 361-383.
19. Kruskal, W. & Wallis, W. Journal of the American. *Journal of the American Statistical Association*, 1952. Vol. 47, N 260, p. 583-621. DOI 10.1080/01621459.1952.10483441
20. Di Rienzo JA., Casanoves F, Balzarini MG, González L, Tablada M, Robledo CW. InfoStat versión 2020. Centro de Transferencia InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. URL: http://www.infostat.com.ar
21. García-Rubio, J. C., de Lena, G. G. G., & Ara, M. C. (2015). El cultivo del kiwi. Servicio Regional de investigación y Desarrollo Agroalimentario (SERIDA).
22. Zimaroieva, A., Zhukov, O. V., Fedoniuk, T., Pinkina, T., & Vlasiuk, V. (2021). Edaphoclimatic factors determining sunflower yields spatiotemporal dynamics in northern Ukraine. *Oilseeds and fats, crops and lipids, 28*(26), 1-13.