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Agradecimientos: Son opcionales y tendrán un máximo de tres renglones para expresar agradecimientos a personas e instituciones que hayan contribuido a la realización del trabajo.

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Race diversity in dryland maize (*Zea mays* L.) landraces from southern Nuevo León, México

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ABSTRACT

Objective: To analyze the race diversity and geographic distribution of the native maize landraces currently cropped at southern Nuevo León, México.

Design/Methodology/Approach: Data was obtained from 41 accessions which represent the commercial production in the dry land area, where fertilization and pest control are scarcely used. Landraces were classified according to the CONABIO guidelines for ear traits.

Results: The measured accessions correspond to seven maize races and to seven interracial crosses. The two most frequent maize races were Ratón and Cónico Norteño, mainly located in the dry areas with less rain.

Study Limitations/Implications: Three races, Celaya, Tablilla de Ocho and Elotes Cónicos, had not been previously reported; while two formerly reported races Tabloncillo and Olotillo, were no longer found. This study did not include the grain-colored accessions.

Findings/Conclusions: Three collections stood out for producing large cobs with large kernels, thus showing a high yield potential. The maize landraces harvested in dryland areas might offer advantages to be grown under harsh environments or be used as gene donors for drought tolerance.

Key words: ear diversity, native maize, race, dryland, *Zea mays*.

INTRODUCTION

México is considered the center of origin, domestication and diversification of maize (*Zea mays* L.), whose genetic diversity is distributed in 59 races (Kato *et al*., 2009). In Nuevo León, maize landraces are located in marginalized dryland zones such as the Sierra Madre Oriental (Acosta-Díaz *et al*., 2014). In this region maize constitutes 93% of the cultivated dryland surface, with a kernel yield that ranges between 0.34 and 1.1 t ha^{-1} (SIAP, 2019). Acosta-Díaz *et al*. (2014) detected the presence of five races in this region: Cónico Norteño, Olotillo, Ratón, Tuxpeño, and Tuxpeño Norteño. But there are still unexplored zones in the region, such

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as the Gral. Zaragoza municipality, where in 2019 there were still no records of native maize varieties (CONABIO, 2019).

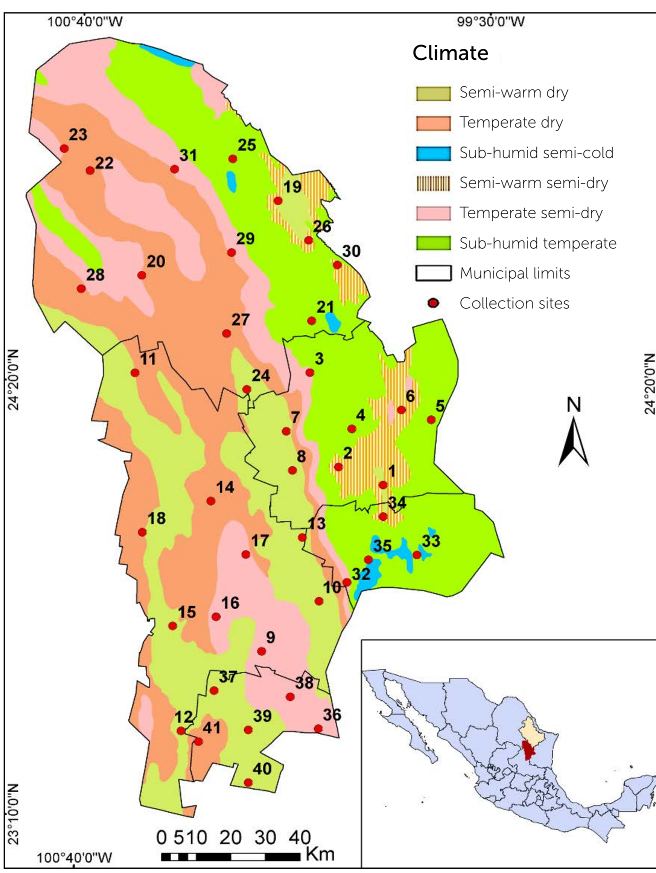
Studying native maize is important to ensure its survival; to understand its genetic diversity and geographic distribution; to maintain successful production processes, understanding the form, speed and causes of genetic erosion; and to plan strategies for its use and conservation (Dwivedi *et al*., 2016; Azeez *et al*., 2018). Currently, global climate change emphasizes the need to use genotypes that are better adapted to unfavorable climates, and the native varieties can contain adaptation genes to such marginal conditions (Hellin *et al*., 2014). Here, the diversity and distribution of native maize landraces was explored in drylands of southern Nuevo León, México, to classify races by cob type and to identify outstanding germplasm for use in maize plant breeding programs.

MATERIALS AND METHODS

In February 2016, native maize samples were collected from 41 localities in the Sierra Madre Oriental region located in the south of Nuevo León state, México, with differences in climate, altitude, and geographic location (Figure 1).

Forty maize cobs per accession were collected, taken from the plot or warehouse of one producer per locality, except in the communities of Carpintería and Refugio, where the producers had already de-kernelled the corn, so therefore only 1.0 kg of grain and less than five cobs were collected from each community. This sample size was considered sufficient for the race classification of the cobs, but insufficient to be included in the statistical analysis of cob diversity. In each collection, information from the production unit was registered based on the Passport Sheet for the Collection of Native Maize (CONABIO, 2019).

The diversity analysis was carried out in n=10 cobs, representative of each of the 39 accessions. Each cob was measured for: diameter (ED, mm), longitude (EL, cm), weight (EW, g), cob diameter (mm), number of rows (NR), kernels per row (KR), number of total kernels (product of NR × KR), total grain weight (TGW, g),



ID	Location	Alt (m)	PP (mm)
1	Carpintería	1170	500
2	Escondida	1522	600
3	Presa de Ánimas	1927	450
4	Puerto de Anteojitos	2054	600
5	Rodeo	1049	900
6	Sacramento	1347	650
7	Sandia el Grande	1579	350
8	Trinidad	1604	350
9	Altitos	1916	500
10	Antonio Peña Nevada	1485	350
11	Boquilla	1773	300
12	Catorce	1700	400
13	Jesús M. Berrones	1594	350
14	Refugio de Cedillo	1922	350
15	San Gregorio	1720	400
16	Santa Anita	1898	450
17	Santa María	1855	450
18	Yerba	1747	350
19	Barrio de Jalisco	1703	450
20	Carmen	1968	400
21	Crucitas	2349	650
22	Delicias	1917	400
23	Hediodilla	1882	400
24	Ignacio de Texas	1679	350
25	Lagunita	2353	600
26	Poza	1739	450
27	Salero	1828	350
28	San Juan de Dios	1924	350
29	Tokio	1889	400
30	Tomates	1561	550
31	Trinidad	1882	400
32	Joya de San Lázaro	2069	450
33	Refugio	2397	800
34	Sabanilla	1445	550
35	Siberia	2619	700
36	Cardona	1911	500
37	Cuatro Caminos	1516	400
38	Lagunita de Taberna	2042	500
39	Lindero	1421	400
40	San Isidro	1229	400
41	Tapona Moreña	1832	400

Figure 1. Geographic location of 41 Creole corn accessions from Nuevo León, Mexico. ID: Accession number. Alt: Altitude. PP: Annual precipitation. Map source and climates: INEGI (2019).

weight of 100 kernels (g), percentage of de-kernelling (TGW/EW ratio, multiplied by 100) and the ED/EL ratio. Furthermore, qualitative variables were measured such as cob shape, arrangement of rows, type and color of kernel, and cob color, based on the Practical Guide for the Preliminary Description of Native Maize Collections (CONABIO, 2019).

The information about the production units was reported in units of relative frequency with regard to the total of interviewed producers. With the accession averages of each quantitative variable, a cluster analysis was performed by using a Euclidian distances matrix and the unweighted pair group method with arithmetic mean (UPGMA) (Gan *et al.*, 2007). The optimal number of clusters was determined with the "NbClust" function (Charrad *et al.*, 2014) of the R program (R Core Team, 2019). The variability between groups of accessions resulting from the cluster analysis was determined by means of an analysis of variance according to a completely randomized design where the number of repetitions corresponded to the number of accessions per group or subgroup. The multiple means comparison was done with Tukey's test ($p \leq 0.05$), using the SAS 9.4 software (SAS Institute, 2015).

RESULTS AND DISCUSSION

Characteristics of production systems

Producers in southern Nuevo León sow maize seeds between February and July and harvest between June and November. They are unaware of the phenology of their varieties and the average grain or fodder yields they produce, because these characteristics vary from year to year depending on the amount of rainfall during the cultivation cycle. Maize grain is mainly destined for self-consumption, and surpluses are sold locally (Table 1). Maize is grown alone or in association with squash (*Cucurbita pepo*), pea (*Pisum sativum*) or bean (*Phaseolus vulgaris*).

Table 1. Characteristics of the production systems for maize landraces cultivated at the Sierra Madre Oriental in the Southern region of the state of Nuevo León, México.

Characteristic	% of farmers
Traction technology	
Animal	42
Mechanic (tractor)	58
Cropping system	
Monoculture	56
Polyculture	44
Warehouse pests	
None	20
Weevil	53
Moths	7
Weevil and moths	9
Weevil and fungus	4
Rodents	7
Use of fertilizers	
None	92
Goat manure	4
Chemical fertilizer	4
Farmer age groups (years)	
< 40	7
From 40 to 50	22
From 51 to 60	31
> 60	40
Uses of maize products	
Only for tortillas	24
Tortillas and forage	76
Destiny of kernels	
Self-consumption	67
Sale	2
Both	31
No. of maize varieties used	
One	38
Two	47
Three or more	15

It is notable that 93% of producers are over the age of 40, and 40% are over 60 years of age. This proportions are worrying, as in the rest of the country, because only growers under 40 (7%) will remain as custodians of the diversity of maize, and this situation puts at risk the conservation and evolution of native maize. Young people's low interest in maize production in the drylands can be attributed to the low or null profitability, derived from low yields and low-tech production systems, as 42% of growers use animals for farm labor, 56% plant in monoculture, 80% report pest problems in storage and none of them have a pest control plan, and 92% of them do not fertilize.

Race classification

In the 41 native maize accessions, six pure races were identified (Table 2 and Figure 2), which represented 63% of collected samples, and one interracial combined race. The interracial crosses represented 37% of the total collected samples (Table 2 and Figure 3). These results show the importance of interracial combinations which contribute to the genetic recombinations ocurring through the flow of pollen and the exchange of seeds between growers (Martínez-Sánchez *et al.*, 2017), which could also imply the development of new germplasm with different characteristics from those of the pure races (Acosta-Díaz *et al.*, 2014).

Other than the four landraces (Cónico Norteño, Ratón, Tuxpeño and Tuxpeño Norteño) that had previously been reported in this region, Celaya and Tablilla de Ocho were found to be pure races, as well as Elotes Cónicos crossed with Cónico Norteño, which had not been identified in previous collections (Acosta-Díaz *et al*., 2014; CONABIO, 2019). Conversely, this time the Tabloncillo and Olotillo landraces were not found, which had previously been reported in the studied zone (Acosta-Díaz *et al*., 2014; CONABIO, 2019). It is possible that a loss of germplasm has occurred in the last few years, but a more precise verification of this would be needed.

Table 2. Six landraces and seven inter-racial crosses detected in 41 native maize accessions from the dryland region in Southern Nuevo León state, México.

No.	Landrace classification	Amount of accessions
	Races	
1	Ratón	8
2	Tuxpeño	6
3	Cónico Norteño	5
4	Tuxpeño Norteño	3
5	Celaya	3
6	Tablilla de Ocho	1
	Inter-racial crosses	
1	CN × R/R × CN	5
2	R × C/C × R	3
3	CN × TN	3
4	CN × C	1
5	CN × EC	1
6	R × TN	1
7	R × T	1

C: Celaya, CN: Cónico Norteño, R: Ratón, T: Tuxpeño, TN: Tuxpeño Norteño, EC: Elotes Cónicos.

In terms of the geographic location of the landraces, Ratón and Celaya were found primarily in arid and semi-arid climates with low annual precipitation (from 300 to 550 mm), and in altitudes between 1445 and 2069 m. The Cónico Norteño landrace was found in a broader range of altitudes (from 1170 to 2619 m) and of rainfall (from 350 to 800 mm), with presence in the six climates of the region, which suggests ample environmental adaptability of this landrace. The two most abundant landraces in the area were Ratón and Cónico Norteño, both in pure races and interracial crosses, present in 44 and 36% of all the collected accessions, respectively. It had previously been reported that these two landraces are the ones preferred by the region's producers, due to their ample adaptability to conditions of limited precipitation, extreme temperatures, and different altitudes, to their short growth cycle and to their use for tortillas and other masa-derived products (Reveles-Torres *et al*., 2014; CONABIO, 2019).

The seven maize landraces detected in this study correspond to an intermediate diversity, compared to that reported in Quintana Roo, Yucatán, Baja California Sur, Tlaxcala, Campeche, and Tabasco, where three to four varieties have been identified per entity. In contrast, in states with high maize diversity, 22 (Veracruz), 21 (Michoacán) and 17 (in Oaxaca and in Jalisco) landraces have been identified (Lazos and Chauvet, 2012).

Figura 2. Cobs of races identified in native maize (*Zea mays* L.) from southern Nuevo León, México. R: Ratón, T: Tuxpeño, CN: Cónico Norteño, TN: Tuxpeño Norteño, C: Celaya y TO: Tablilla de ocho.

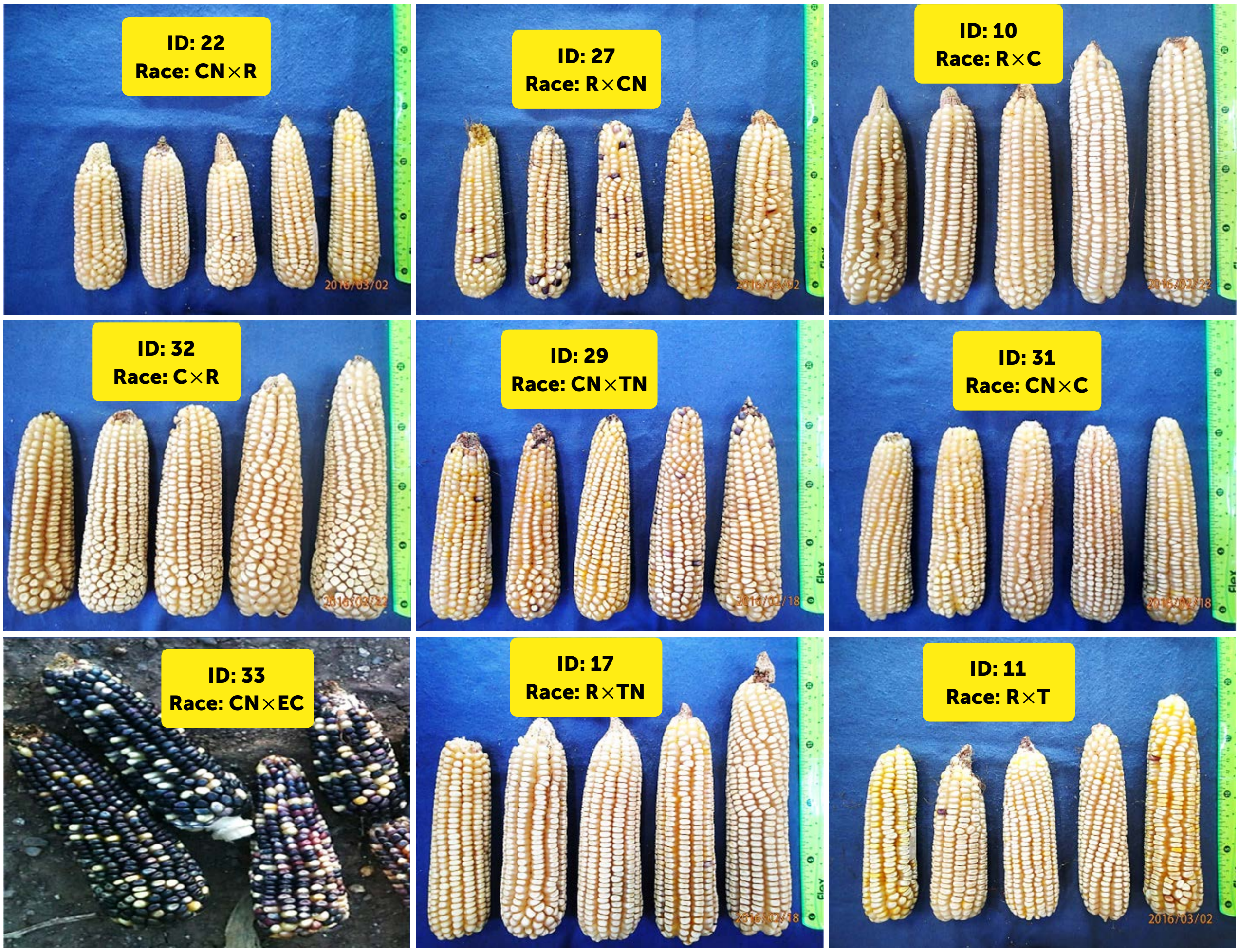


Figura 3. Cobs of interracial crosses identified in native maize (*Zea mays* L.) from southern Nuevo León, México. R: Ratón, T: Tuxpeño, CN: Cónico Norteño, TN: Tuxpeño Norteño, C: Celaya, y EC: Elotes Cónicos.

Characteristics of the cobs. Two accession groups were identified in the cobs. The first (G1) was formed by 20 accessions with two sub-groups, SG1-1 and SG1-2; the second (G2) was established by 19 accessions with three subgroups, SG2-1, SG2-2 and SG2-3 (Figure 4). G2 presented greater values in quantitative values of the cobs (except in ED/EL), with 20% more cobs with straight rows and 12% more of the dent variety of kernels, compared to G1 (Table 3). In the sub-groups, the greatest contrasts were found between SG2-2 and

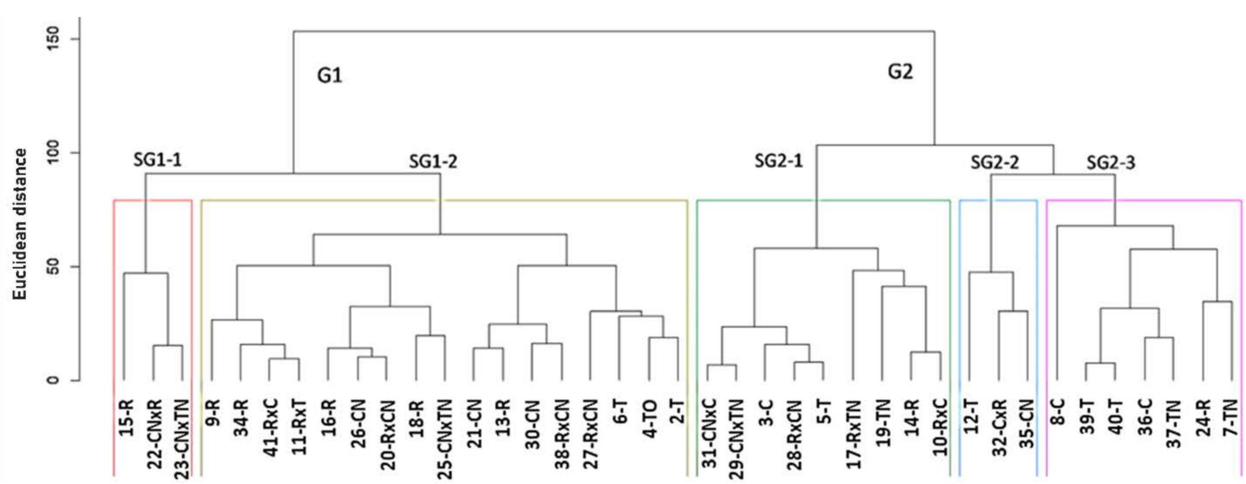


Figure 4. Dendrogram of the grouping of 39 accessions of corn (*Zea mays* L.), obtained by the UPGMA method. The name includes the collection number and racial classification identified in Figure 1. G = group. SG = subgroup.

Table 3. Relative frequency (%) of quantitative and qualitative traits of maize ears classified in two groups and five subgroups of landraces grwon at Southern región of Nuevo León state, México.

Cob characteristic		Groups		Subgroups				
Quantitative traits		G1	G2	SG1-1	SG1-2	SG2-1	SG2-2	SG2-3
Diameter (mm)		40.9 B	45.2 A	38.5 d	41.3 c	43.2 c	49.5 a	46 b
Length (cm)		14.8 B	16.2 A	13.3 c	15.1 b	15.9 b	18.2 a	15.8 b
Weight (g)		133 B	184 A	95.1 d	139 c	165 b	245 a	182 b
Cob diameter (mm)		21.9 B	23.5 A	20.5 c	22.1 bc	22.9 b	25.1 a	23.6 ab
Rows per ear		12.4 B	14.3 A	12.4 c	12.4 c	13.6 b	14.7 ab	14.9 a
Kernel number per row		33.4 B	37.9 A	29.1 c	34.1 b	36.8 ab	37.8 a	39.4 a
Kernel number per ear		413 B	540 A	363 d	421 c	502 b	550 a	586 a
Total kernel weight (g)		114 B	160 A	87 d	119 c	144 b	206 a	160 b
Weight 100 grains (g)		28.5 B	31.2 A	24.5 c	29.2 b	30.0 b	40.6 a	28.9 b
Per cent of kernels (%)		85.5 B	87.1 A	84.5 a	85.7 a	87.2 a	84.7 a	88 a
Diameter/length ratio		2.7 A	2.8 A	2.9 a	2.7 a	2.7 a	2.7 a	2.9 a
Qualitative traits		G1	G2	SG1-1	SG1-2	SG2-1	SG2-2	SG2-3
Shape	Conical	6.8	10.0	33.3	1.9	1.1	33.3	11.4
	Conical- cylindrical	73.2	65.8	50.0	77.5	77.8	46.7	58.6
	Cylindrical	20.0	24.2	16.7	20.6	21.1	20.0	30.0
Row arrangement	Regular	72.2	56.8	90.0	68.8	48.9	83.3	55.7
	Irregular	0.5	2.1	0.0	0.6	3.3	0.0	1.4
	Straight	26.8	40.6	10.0	30.0	46.7	16.7	42.9
	Helicoidal	0.5	0.5	0.0	0.6	1.1	0.0	0.0
Kernel type	Floury	0.0	0.5	0.0	0.0	0.0	0.0	1.4
	Dent	12.6	26.8	0.0	15.0	12.2	33.3	42.9
	Semi-dent	44.2	51.1	53.3	42.5	45.6	56.7	55.7
	Semi-flint	41.6	21.6	46.7	40.6	42.2	10	0.0
	Flint	1.6	0.0	0.0	1.9	0.0	0.0	0.0
Kernel color	White	82.1	97.4	66.7	85	94.4	100	100
	Pale yellow	5.3	0.0	33.3	0.0	0.0	0.0	0.0
	Yellow	12.6	2.6	0.0	15.0	5.6	0.0	0.0
Cob color	White	87.4	82.1	86.7	87.5	78.9	83.3	85.7
	Red	12.6	17.9	13.3	12.5	21.1	16.7	14.3

G: group; SG: subgroup. Different capital letters in a row mark significant differences between the two groups; different letters in a row mark significant differences among the five subgroups (Tukey, $p \leq 0.05$).

SG1-1; sub-group SG2-2 consisted of Catorce (Tuxpeño), Joya de San Lázaro (Celaya × Ratón) and Siberia (Cónico Norteño), and presented higher values in cob size, but not in DESG or ED/EL, as well as a higher proportion of conical shaped cobs, with straighter rows, dent and semi-dent kernels, compared to sub-group SG1-1.

The number and weight of kernels per cob are components of yield, and as such they are useful characteristics to consider in genetic plant breeding (Pecina *et al.*, 2011). Sub-groups SG2-2 and SG2-3 are the ones with the highest number of kernels per cob (550 and 586, respectively), and SG2-2 is the one with the largest kernels and greater weight of grain per cob. The SG2-2 accessions were collected in localities with higher altitude (2129 m) and annual precipitation (517 mm), where the most favorable environments are and where a greater yield is harvested.

The differences ($p \leq 0.05$) between race groups in terms of cob characteristics indicate that such traits were useful for exploring and analyzing the diversity of native maize landraces. The results obtained confirm that the selection made by the farmers themselves has improved these and other characteristics of the maize by giving rise to varieties suitable for production in these environments, as proposed by Hortelano *et al*. (2012).

CONCLUSIONS

Among native maize of southern Nuevo León, there is diversity in races and cob characteristics. Seven landraces have been identified: Celaya, Cónico Norteño, Ratón, Tuxpeño, Tuxpeño Norteño, Tablilla de Ocho and Elotes Cónicos. The races with the most accessions in the region were Ratón and Cónico Norteño, especially in the regions with less rainfall. Three landraces (Celaya, Tablilla de Ocho and Elotes Cónicos) had not been reported in previous collections. Three collections stand out for having large cobs with the large kernels (Catorce [Tuxpeño race], Joya de San Lázaro [a cross between races Celaya × Ratón], and Siberia (Cónico Norteño race), with the potential for high grain yield production. The varieties of native maize from southern Nuevo León are grown in marginal conditions and can offer advantages as genetic sources of adaptability to drought and other adverse environments.

REFERENCES

Acosta-Díaz, E., Zavala-García, F., Valadez-Gutiérrez, J., Hernández-Torres, I., Amador-Ramírez, M. D., & Padilla-Ramírez, J. S. (2014). Exploración de germoplasma nativo de maíz en Nuevo León, México. Revista Mexicana de Ciencias Agrícolas 8: 1477-1485.

Azeez, M. A., Adubi, A. O., & Durodola F. A. (2018). Landraces and crop genetic improvement. *In*: O. Grillo (Eds.). Rediscovery of Landraces as a Resource for the Future (pp: 1-19). IntechOpen. London. doi: https://doi.org/10.5772/ intechopen.75944.

Charrad, M., Ghazzali, N., Boiteau, V., & Niknafs, A. (2014). NbClust: An R package for determining the relevant number of clusters in a data set. Journal of Statistical Software 61: 1-36. doi: 10.18637/jss.v061.i06.

CONABIO, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. (2019). Proyecto global de maíces nativos. Razas de maíz de México. Base de datos 2017. Anexo 7: guía de colecta. Anexo 12: exploración y colecta. Recuperado de: https://www.biodiversidad.gob.mx/genes/proyectoMaices.html

Dwivedi, S. L., Ceccarelli, S., Blair, M. W., Upadhyaya, H. D., Are, A. K., & Ortiz R. (2016). Landrace germplasm for improving yield and abiotic stress adaptation. Trends in Plant Science 21: 31-42. doi: https://doi.org/10.1016/j.tplants.2015.10.012

Gan, G., Ma, C. & Wu, J. (2007). Data Clustering: Theory, Algorithms, and Applications. ASA-SIAM Series on Statistics and Applied Probability, SIAM, Philadelphia, ASA, Alexandria, Virginia, EUA.

Hellin, J., Bellon, M. R., & Hearne, S. J. (2014). Maize landraces and adaptation to climate change in Mexico. Journal of Crop Improvement 28: 484-501. doi: https://doi.org/10.1080/15427528.2014.921800

Hortelano-Santa, R., Gil-Muñoz, A., Santacruz-Varela, A., H. López-Sanchez, H., López-Antonio P., & Miranda-Colín, S. (2012). Diversidad fenotípica de maíces nativos del altiplano centro-oriente del estado de Puebla, México. Revista Fitotecnia Mexicana 35: 97-109.

Kato-Yamakake, T. A., Mapes-Sanchez, C., Mera-Ovando, L. M., Serratos-Hernández, J. A., & Bye-Boettler, R. A. (2009). Origen y Diversificación del maíz: Una Revisión Analítica. Universidad Nacional Autónoma de México, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México, D. F. 116 p.

Lazos, E., & Chauvet, M. (2012). Análisis del contexto social y biocultural de las colectas de maíces nativos en México. Proyecto global de maíces nativos. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México. 533 p. Rescatado de: https://www.biodiversidad.gob.mx/media/1/genes/files/analisis_socio_cultural_maices.pdf

Martínez-Sánchez, J., Espinosa-Paz, N., & Cadena-Iñiguez, P. (2017). Caracterización morfológica de poblaciones de maíz nativo (*Zea mays* L.) en Chiapas, México. Agroproductividad 10: 26-33.

Pecina-Martínez, J. A., Mendoza-Castillo, M. C., López-Santillan, J. A., Castillo-González, F., Mendoza-Rodriguez, M., & Ortiz-Cereceres, J. (2011). Rendimiento de grano y sus componentes en maíces nativos de Tamaulipas evaluados en ambientes contrastantes. Revista Fitotecnia Mexicana 34: 85-92.

R Core Team. 2019. R: A Language and environment for statistical computing. Version 3.6.1. Foundation for Statical Computing.

SAS Institute (2015). Statistical analysis software for Windows version 9.4. Cary, North Carolina, USA: SAS Institute.

SIAP, Servicio de información agroalimentaria y pesquera. (2019). Avance de siembras y cosechas. Secretaría de Agricultura y Desarrollo Rural. Ciudad de México. Rescatado de: http://infosiap.siap.gob.mx:8080/agricola_siap_gobmx/ResumenDelegacion.do

Reveles-Torres, L. R., Luna-Flores, M., Mejía-Gurrola, A., Hernández-Martínez J., & García-Hernández, S. (2014). Razas actuales de maíz de secano en el estado de Zacatecas, México. Revista Mexicana de Ciencias Agrícolas 5: 1155-1168.

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Analysis of the Demand for Berries in Mexico: An Application of the Almost Ideal Demand System (AIDS) Model

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ABSTRACT

Objective: To identify the factors affecting the demand for berries in Mexican households, as well as the behavior in face of variations in economic income.

Design/Methodology/Approach: In order to analyze the demand, microdata were used from the National Income-Expenditure Survey of Households 2018 (Encuesta Nacional Ingreso Gasto de los Hogares, ENIGH) from the National Institute of Statistics and Geography (Instituto Nacional de Estadística, Geografía e Informática, INEGI), and for its modelling the Almost Ideal Demand System (AIDS) model was used.

Results: Because of their Marshallian elasticity, berries are an elastic good (−1.0316), and because of their expenditure elasticity they are a luxury good (1.0691). In terms of crossed Marshallian elasticities, sweet fruits and sugary beverages were identified as substitute goods with elasticity of 0.0013 and 0.0380, respectively, while semi-acid fruits and melons would be complementary goods, with elasticities of −0.0191 and −0.0184, respectively.

Study Limitations/Implications: Given that most of the time series of the berries lack disaggregation and sufficient information, it is difficult to analyze each component of the group separately; therefore, it was decided to analyze the group of berries and its relationship with other goods; in addition, the ENIGH database was selected, which provides more information.

Conclusions: There are state differences in the response to changes in prices and income with regard to the demand for berries, so that facing a generalized increase in household income consumption would increase much more in the center of the country than in the south-southeast.

Keywords: berries, elasticity, microdata, demand system.

INTRODUCTION

In Mexico, the national consumption per capita of berries (strawberry, raspberry, blackberry and cherry) increased at an average annual rate of 14.56% in the 2010-2017 period. In 2017, their consumption was 6.95 kg average per inhabitant, which meant more than three times what was observed in 2010 (1.83 kg). The exports of berries have shown a similar dynamic, in average and throughout the same period; the exchange of berries with the rest of the world increased at an annual average rate of 28.17%.

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The importance of berries in the national agrifood market is due to the window of opportunity that consumers of medium and high income represent, who are willing and able to pay a relatively high price compared to other fruit groups and who generally appreciate the products that promote health (FIRA, 2016). There are findings that relate the consumption of berries with positive effects in combatting different types of diseases, for example Miller *et al*. (2019) and Solverson *et al*. (2018)

Such dynamism in the demand, both domestic and foreign, has brought an important increase in the cultivation of these fruits in various regions of the country (Rivera & Blanco, 2018). According to information from FIRA (2016), this has led to Mexico becoming positioned as the fifth world producer of berries (leaving out cherries). Therefore, the factors that affect the demand for berries in Mexican households were identified in this study, with the aim of quantifying its relationship with other products, as well as the behaviors of households in view of variations in their economic income. This was done by estimating the own, expenditure and crossed price elasticities.

MATERIALS AND METHODS

The Mexican demand for berries was modelled using microdata from the ENIGH by INEGI for the year 2018 (https://www.inegi.org.mx/programas/enigh/nc/2018/); specifically, the following sections were used: Expenditure in households (household expenses), Financial and capital income and receipts of members of the household (income), and Main variables per household (household concentrate). These bases (sections) were linked according to their household key. This aggregate base was used to generate six food groups, with emphasis in fruit products, which are components of the expenditure in Mexican households (Table 1).

The inspection of the ENIGH (2018), with the incorporation of the expansion factors (defined as the inverse of the probability of selection, and which is a measure of representativeness per observation), made evident that Mexican households, in general, are not habitual fruit consumers, since out of 74,582 representative households with valid information in the survey, only 1.35% indicated consuming berries (corresponding on average to consumers of high income, see Valdés-Zamora (2020)), 26.32% acid fruits, 33.40% sweet fruits, 22.69% semi-acid, and 7.05% melons. On the other hand, in the case of sugary beverages, 68.87% of the households reported consuming the good.

Having said that, regarding the expense destined solely to the purchase of the six groups analyzed, on average the households destined 0.6942% to purchasing berries, 10.7321% to acid fruits, 13.15251% to sweet fruits, 12.5007 % to purchasing semi-acid fruits, 2.8462% to melons, and 59.38% of the expenditure to the purchase of sugary beverages. This, in part, reaffirms what was exposed previously and it is because Mexican households are not habitual consumers of fruits.

Regarding the logarithm of the average prices that consumer households reported, we find that berries exhibited the highest average price with 4.01, followed by melons with 3.11, acid and semi-acid fruits with 2.5, and sugary beverages with 1.99, which places the latter as the cheapest compared to the fruit groups, which could explain in part their higher preference.

One of the problems when using microdata is that when the households report zero consumption of one of the goods, they generate the price of the product as an absent value; however, to give solution to this problem and not exclude these data, the imputation process known in the literature as k-nearest neighbor imputation (KNN) was used. Only one neighbor was

Table 1. Food groups of fruits and sugary drinks and their components, 2018.

Groups	Components
(1) Berries	Cherry, raspberry, strawberry, blackberry
(2) Acidic fruits	Guava, lime, lemon, tangerine, nectarine, tangerine, grapefruit, orange, pineapple, garambullo, pomegranate, fig, jicama, kiwi, cane, coconut, nanche, tamarind.
(3) Sweet fruits	Chicozapote, mamey, plum, jobo, pitahaya, tuna, bananas, grape.
(4) Semi-acid fruits	Anona, cherimoya, soursop, peach, mango, apricot, peach, ap-ple, peron, papaya
(5) Melons	Watermelon, melon.
(6) Sugary drinks	Prepared water and natural juices, packaged juices and nectars, Concentrates and powders to prepare drinks, Cola and flavor soft drinks and Energy drink.

Source: own elaboration with ENIGH 2018 data.

considered for this procedure (that is, K=1) and the measure of distance was taken from the center of one municipality to another.

The application of KNN to the data is correct under the following assumption: "the costs for transportation of the merchandise from one municipality to its nearest neighbor are small in unitary terms; therefore, two municipalities can share the same price for the fruits" because, if that were not the case, the imputation could underestimate the price of the product in places where there is not a reference price.

The AIDS model

Deaton and Muellbauer (1980) developed a flexible demand system called "Almost Ideal Demand System" (AIDS), which stems from an expenditure function for the PIGLOG type of preferences and the microeconomic theory, to reach the following functional form, feasible to be estimated econometrically.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j + \beta_i \ln\{X/P\} \qquad (1)$$

Where w_i=the participation of the expenditure of group i; α_i=the intercept in the equation of group i; γ_{ij}=the coefficients associated to the interaction of the expenditure from group i and the prices of groups j; P_j=the average prices of goods in group j; β_i=the coefficient associated to the expenditure in group i; X=the total expenditure in the set of groups, and P=the index of translog prices defined by:

$$\ln P = \alpha_0 + \sum_k \alpha_k \ln P_k + \frac{1}{2}\sum_j \cdot \sum_k \gamma_{kj} \ln P_k \log P_j \qquad (2)$$

Where P_k and P_j are the prices of the goods in the groups k and j, respectively.

As Moschini (1998) points out, the AIDS model satisfies automatically the restriction of additivity, homogeneity and symmetry; in the next section, the conditions for each of these restrictions are shown.

Additivity requires:

$$\sum_{i=1}^{n} \alpha_i = 1 \quad \sum_{i=1}^{n} \gamma_{ij} = 0 \quad \sum_{i=1}^{n} \beta_i = 0, \quad (k = 1,2,\ldots n) \qquad (3)$$

The condition of homogeneity is satisfied if and only if for any j:

$$\sum_j \gamma_{ij} = 0 \qquad (4)$$

The symmetry is satisfied if:

$$\gamma_{ij} = \gamma_{ji} \qquad (5)$$

Although in practice it is common to use the Stone price index to linearize the AIDS model and make use of linear estimation methods, such as SUR, it has been shown that this can bring problems of simultaneity bias (Banks *et al*., 1997; Henningsen). And although this has been attempted to be solved by using other price indexes that are not function of the proportions of expenditure, suggestions have been made for time series. This is why it is suggested to estimate the AIDS model in its non-linear version; that is, equation (1) was estimated subject to equations (2) to (5).

For this purpose, the algorithm called Iterative Nonlinear Feasible Generalized Least Squares Regression (FGNLS) of the nlsur package of STATA was used, which is relevant for two reasons: 1) it allows estimating systems of non-linear equations; and 2) it relaxes the assumption of homoscedasticity which implies the use of Nonlinear Least Squares, fact that is relevant when used with data at the household level, given that these structures of data usually are not, since it is common for households to be related with one another (Deaton, 2018).

Although all the parameters in (1) and (2) are identified with sufficient variation of independent variables, in many cases the identification of α_0 (in equation 2) could be problematic. However, this can be surpassed in the practice by assigning a value to α_0 *a priori*, given that the parameter can be interpreted as the minimum disbursement of households for the purchase of the groups of goods analyzed (Deaton & Muellbauer, 1980).

This is why in the empirical applications it has been suggested to equal this parameter to the minimum value of the logarithm of the expenditure observed in the microdata (Banks, Blundell, and Lewbel, 1997). In this study, α_0=0 is proposed, which leads to the index of translog prices base (2) being the unit, P=1. In addition, as mentioned in Valdes-Zamora (2020), for different values of α_0, the estimators do not cease to be statistically equal.

To obtain the elasticities from the AIDS model, it was based on Henningsen. In the case of the expenditure elasticity (e_i), it is obtained when applying the following equation:

$$e_i = 1 + \left(\frac{1}{w_i}\right)\left(\frac{\partial w_i}{\partial \ln(x)}\right) = 1 + \left(\frac{\beta_i}{w_i}\right)$$

In turn, the Marshallian elasticities (e_{ij}) are obtained in the following way:

$$e_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(\alpha_j + \sum_{k=1}^{n} \gamma_{kj} \ln P_k\right)$$

Where δ_{ij} is Kronecker's delta that is the unit if $i=j$, and zero in the contrary case. It should be noted that the elasticities reported next are national averages and these are obtained as follows: the formulas exposed before are applied to each household and then the mean is obtained by applying their expansion factors.

RESULTS AND DISCUSSION

Table 2 presents the results from the estimations of the AIDS model, on which the restrictions of additivity, homogeneity and symmetry were imposed. The standard error of each estimator is reported in parenthesis.

For the equation for berries, the estimator that relates them with the expenditure and own price were significant at 95% of confidence; as well as those related to the price of the sweet fruits, semi-acid fruits, melons and sugary beverages.

In terms of crossed Marshallian elasticities (Table 3), and considering the significance of the crossed parameters, it is found that substitute goods of berries would be sweet fruits and sugary beverages; meanwhile, semi-acid fruits and melons would be complementary.

Regarding the own price Marshallian elasticity (main diagonal in Table 3), the six groups analyzed are classified as elastic goods. In particular, for berries, an increase of 1% in their price, ceteris paribus, is associated to a reduction in the quantity demanded by households of 1.0316%. This result differs from what was found in studies by Martinez and Oropeza (2004) and López *et al.* (2010); these studies catalogue the fruits that they researched (orange, banana, mango, melon, peach, watermelon, guava, papaya, strawberry, pineapple and grapefruit), and which are part of the groups analyzed, as inelastic goods.

This difference can be because in their studies the authors use prices at the farm level and not prices to the consumer, so they would be estimating the demand elasticities derived or in production, and not the primary or consumption demand,

Table 2. AIDS model estimators.

	α	β	γ_{i1}	γ_{i2}	γ_{i3}	γ_{i4}	γ_{i5}	γ_{i6}
Berries	0.0050*	0.0153*	−0.0067*					
	(0.0007)	(0.0003)	(0.0004)					
Acidic fruits	0.1438*	0.0024*	0.0004	−0.0380*				
	(0.0019)	(0.0012)	(0.0004)	(0.0018)				
Sweet fruits	0.1513*	0.0263*	0.0010*	−0.0040*	−0.0285*			
	(0.0020)	(0.0012)	(0.0004)	(0.0014)	(0.0019)			
Semi-acidfruits	0.0918*	0.1002*	−0.0041*	−0.0024*	−0.0220*	−0.0578*		
	(0.0020)	(0.0011)	(0.0005)	(0.0014)	(0.0015)	(0.0020)		
Melons	0.0205*	0.0314*	−0.0036*	0.0083	0.0035*	−0.0139*	−0.0245*	
	(0.0011)	(0.0006)	(0.0005)	(0.0009)	(0.0010)	(0.0011)	(0.0013)	
Sugary drinks	0.5876*	−0.1757*	0.0130*	0.0358*	0.0501*	0.1003*	0.0303*	0.2296*
	(0.0028)	(0.0018)	(0.0003)	(0.0012)	(0.0013)	(0.0013)	(0.0007)	(0.0022)

The asterisk (*) after the estimator refers to the fact that the estimator value is statistically nonzero at 95% confidence. Due to symmetry condition, for example, $\gamma_{12}=\gamma_{21}$, the estimator matrix has empty cells. Source: own elaboration.

Table 3. Marshallian elasticities.

Group	Berries	Acidic fruits	Sweet fruits	Semi-acid fruits	Melons	Sugary drinks	Expenditure Elasticity
Berries	−1.0316	−0.0089	−0.0079	−0.0297	−0.0199	0.0289	1.0691
Acidic fruits	0.0015	−1.1806	−0.0209	−0.0135	0.0382	0.1639	1.0115
Sweet fruits	0.0013	−0.0347	−1.1412	−0.1133	0.0085	0.1676	1.1118
Semi-acidfruits	−0.0191	−0.0545	−0.1201	−1.2244	−0.0575	0.1759	1.2998
Melons	−0.0184	0.0141	−0.0092	−0.0812	−1.1107	0.0718	1.1336
Sugary drinks	0.0380	0.1409	0.1820	0.2919	0.0879	−1.3614	0.6207

Source: own elaboration with ENIGH 2018 data.

and as is known, the primary demand is more elastic than the derived demand.

It should be mentioned that for the case of sugary beverages, the estimations are similar to what was found by Colchero *et al*. (2015), who estimated the own price elasticity of 1.16 in absolute terms, while the one found in this study is 1.3614.

In terms of expenditure elasticities (last column in Table 3), it is found that for all the groups of fruits the expenditure elasticity is higher than one, while sugary beverages are the only ones with elasticities lower than one. That is, based on this, fruits would be luxury goods and sugary beverages a necessary good for the households.

The results obtained for the groups of fruits are similar to those found by Dong *et al*. (2002), since in their study they classify the aggregate of fruits as luxury goods when reporting an expenditure elasticity of 1.2762. However, they differ in part from those found by Martinez and Oropeza (2004), since in that study they only classified the melons and oranges as luxury goods, while the rest of the fruits analyzed as necessary goods. López *et al*. (2010) also reported in their study that not all citruses were luxury goods.

One of the virtues of working with microdata vs time series is the incorporation of demographic variables. In this sense, although they were not incorporated in the estimation of the AIDS model, when obtaining the elasticities per household it was possible to recover the average elasticities at the state level (Figure 1).

Figure 1 shows maps of the national territory and on them the own expenditure and price elasticities at the level of state household for berries, obtained from the AIDS model.

The interpretation of expenditure elasticities (left side) is evident, darker tonalities reflect higher expenditure elasticities; in this sense, states in the center of the country like Puebla and Querétaro exhibit the highest expenditure elasticities (1.079 and 1.076, respectively), while Tabasco and southeastern states (Yucatán, Quintana Roo) present the lowest expenditure elasticities (1.0465, 1.0504 and 1.0514), respectively.

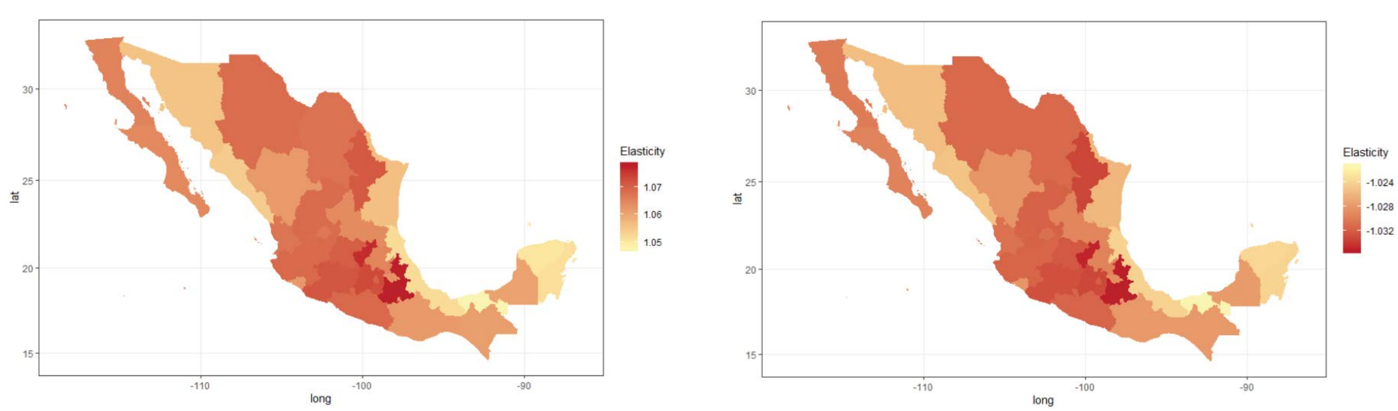

Figure 1. Statewide average expenditure (left side) and Marshallian own price elasticities (right side), AIDS model. Source: own elaboration with ENIGH 2018 data.

In terms of the own price elasticities of berries (Figure 1 B), darker tonalities are related to higher elasticities in absolute terms. Thus, and contrary to the case of expenditure elasticity, states like Veracruz and south and southeastern states are less elastic to changes in the price of berries, while in the center of the country (Puebla and Querétaro) there are higher elasticities.

This accounts for the heterogeneity that demand for berries has in the long term. It would be expected to observe that, facing a generalized increase of expenditure, the consumption would increase much more in the center of the country versus the south-southeast. Meanwhile, if the price increases in the same way, the trend would be different; that is, a greater contraction of the consumption in the center of the country versus the south-southeast would be expected.

CONCLUSIONS

According to the own price elasticity of berries and sugary beverages analyzed, it is found that all of them are elastic goods (E_p>1); in terms of crossed Marshalian elasticities, it was found that according to the model, the substitute goods for berries would be sugary beverages (E_{ij}=0.0289); meanwhile, the sweet fruits, semi-acid fruits and melons would be complementary ($E_{ij}=-0.079$, $E_{ij}=-0.0297$, E_{ij}=0.0199, respectively).

When analyzing the expenditure elasticities, berries, same as the rest of the fruit groups, are luxury goods with elasticities higher than one. For berries, the average elasticity is 1.0691. The opposite is the case of sugary beverages, with elasticity of 0.6207, which classifies it as a necessary good. Finally, in light of the findings mentioned of national average, there is also the fact that there are state differences in the response to changes in prices and income compared to the demand for berries, so that in the long term, it would be expected to observe that when facing a generalized increase of income in the households, the consumption will increase much more in the center of the country versus the south-southeast, contrary case to a generalized increase of their price.

REFERENCES

Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel Curves and Consumer Demand. The Review of Economics and Statistics, 79(4), 527–539.

Colchero, M. A., Salgado, J. C., Unar-Munguía, M., Hernández-Ávila, M., & Rivera-Dommarco, J. A. (2015). Price elasticity of the demand for sugar sweetened beverages and soft drinks in Mexico. Economics & Human Biology, 19, 129–137. https://doi.org/https://doi.org/10.1016/j.ehb.2015.08.007

Deaton, A. (2018). The analysis of household surveys (1st ed.). Washington, D.C.: Worl Bank.

Deaton, A., & Muellbauer, J. (1980). An Almost Ideal Demand System, (1954).

Dong, D., Gould, B. W., & Kaiser, H. M. (2002). The Structure of Food Demand in Mexico: An Application of the Amemiya-Tobin Approach to the Estimation of a Censored System. 2002 Annual Meeting American Agricultural Economics Association Long Beach, CA.

FIRA. (2016). Panorama Agroalimentario | Berries 2016. Fideicomisos Instituidos en Relacion con la agricultura (Vol. 2016).

Henningsen, A. (n.d.). Demand Analysis with the "Almost Ideal Demand System" in R : Package micEconAids.

López, M. A., Valdivia, R., Hernández, J., & Romo, J. L. (2010). Elasticidades y flexibilidades de los productos citrícolas en México Elasticities and flexibilities of citrus products in Mexico. Revista Mexicana de Economia Agricola y de Los Recursos Naturales, III(2), 97–112.

Martinez, M. Á., & Oropeza, J. A. (2004). Un sistema de Demanda Casi Ideal (AIDS) aplicado a once frutas en México (1960-1998). Revista Fitotecnia Mexicana, 27(4), 367–375.

Miller, K., Feucht, W., & Schmid, M. (2019). Bioactive Compounds of Strawberry and Blueberry and Their Potential Health Effects Based on Human Intervention Studies: A Brief Overview. Nutrients, 11(7), 1510. https://doi.org/10.3390/nu11071510

Moschini, G. (1998). The semiflexible almost idela demand system. European Economic Review, 42(2), 349–364.

Rivera, J., & Blanco, J. (2018). Berries: Rutas Tecnológicas 2014-2018. Jalisco, México.

Solverson, P. M., Rumpler, W. V, Leger, J. L., Redan, B. W., Ferruzzi, M. G., Baer, D. J., … Novotny, J. A. (2018). Blackberry Feeding Increases Fat Oxidation and Improves Insulin Sensitivity in Overweight and Obese Males. Nutrients, 10(8), 1048. https://doi.org/10.3390/nu10081048

https://doi.org/10.32854/agrop.v14i05.1765

Production and Commercialization of *Helianthus annuus* L. for Cut Flowers in Texcoco, Mexico

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ABSTRACT

Objective: To evaluate the process of sunflower production (*Helianthus annuus* L.) for fresh cutting flowers, considering two sowing dates, growing degree-days, and commercialization.

Design/Methodology/Approach: A completely randomized experimental design with subsampling was used, with five repetitions per treatment (sowing date), in order to analyze the variables: number of leaves, height, and flower diameter. Vincent Choice Dark Eye Ball™ sunflowers seeds were sown in black plastic boxes with 8 cm of soil on January 31 and February 11, 2020, at 153 plants per m^{-2} in a greenhouse. Later, the seedlings were grown in the open field until harvesting, after which they were given added value and then locally traded. In addition, the growing degree-days (GDD) were calculated.

Results: The sunflowers registered a height of 55 cm, 13 leaves per stalk, and a flower diameter of 6.88 cm. Late sowing favored the height and diameter of the flower. The sunflower hybrid required more GDD to reach commercial flower maturity in the first sowing date. The cost-benefit ratio was 1.38.

Study Limitations/Implications: Seeds were sown on only two dates.

Findings/Conclusions: The production process involved planning, management, and commercialization. The sunflower hybrid required on average 499 GDD to reach the cutting point. The added value increased the price fivefold.

Key words: floriculture, productive process, sunflower, added value.

INTRODUCTION

The sunflower (*Helianthus annuus* L.) is native to North America (Andrew *et al*., 2013) and is cultivated for edible seed production, oil extraction, or for ornamental production. The sunflowers cultivated in Mexico are hybrids (Bye *et al*., 2009). In 2018, the surface area planted with ornamental sunflower in Mexico was 757 hectares with 384,495 stands (144 stalks) and a production value higher than 114

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million pesos (SIAP, 2018). The production of ornamental sunflower occurs in the states of Baja California, Estado de México, Morelos, Puebla, and Sonora; however, this crop has high production potential in other states in the country, due its capacity to adapt to diverse climates. At a temperature lower than 4 °C, sunflower does not germinate, and therefore in temperate regions it is germinated in greenhouses (Alba and Llanos, 1990). Different sowing dates can cause differences during the development stages of the crop due to ambient temperatures (Baghdadi *et al.*, 2014). Sunflower hybrids require a different amount growing degree-days (GDD) for each of the phenological stages. The most commonly used temperature index to estimate the plant's development is the GDD and its accumulation allows for determining the maturity of the plant (Qadir *et al.*, 2007). The ornamental sunflower can be sown at densities of 60 plants per m^{-2} while preserving their commercial quality (Vera-Montenegro and Chavarría, 2010). In this study some variables of the cutting sunflower crop are reported, cultivated in the open field considering two sowing dates, GDD, and commercialization.

Figure 1. Sunflower seeds and seedlings in black plastic boxes.

MATERIALS AND METHODOLOGY

The study was conducted outdoors in the Montecillo Campus of Colegio de Postgraduados, in Montecillo, Texcoco, Estado de México (19.52° N, 98.88° W at an altitude of 2,250 m). The climate is subhumid temperate with summer rains. The average annual temperature is 14.6 °C and the precipitation is 558.5 mm (Escalante-Estrada *et al.*, 2015). Germination occurred in a gable-type greenhouse with lateral anti-trip mesh netting.

Germination stage

The Vincent Choice Dark Eye Ball™ seeds, resistant to low temperatures, were sown in 8 cm of 1:1 peat moss substrate and hill soil within black 57 cm long × 36.5 cm wide × 22.5 cm high plastic boxes. The bottom was covered in newspaper to avoid loss of substrate (Figure 1).

Figure 2. Sunflower seedlings of 10 days (up) and 21 days (down) germinated in the greenhouse and placed outdoors.

Sowing took place on January 31 and February 11, at a depth of 2.5 cm with a planting density of 153 plants per m^{-2}, and substrate humidity was maintained at field capacity with manual irrigation. The experiment was conducted in a completely randomized design (CRD), with five repetitions per treatment, sowing date, to analyze the variables of number of leaves, height, and flower diameter. The data were analyzed as a CRD with subsampling (Zamudio and Alvarado, 1994), using the statistical software SAS (v. 9.3, SAS Institute, Inc). The multiple means comparison test was done with Tukey's method with a significance level of 5%.

Vegetative stage in the open field

Temperature influences the development of sunflower, so the seedlings were transplanted to the field once the daily minimum temperature was above 7 °C (Figure 2). The first transfer date was at 21 days, and the second date with seedlings at 10 days after sowing (DAS), under integral pest and disease management. At 10 DAS, weekly fertilizer use began, using a foliar fertilizer with N11%, P8%, K6%, and micronutrients at a dosage of 20 mL in 10 L of water. After a month, triple 18 was applied (18N-18P-18K) at a dosage of 1kg ha^{-1} in the weekly irrigation.

Harvesting stage

Ninety-eight percent (98%) of germinated seeds produced a commercial-quality flower for cutting. Harvesting occurred at 62 days for the first sowing date and 54 days for the second sowing. Daily temperature readings from the agrometeorological station in Colegio de Postgraduados were registered and used, and a base temperature (Tb) of 6.6 °C was used as suggested by Hammer *et al*. (1982) to calculate GDD for each development stage, as per the visual scale proposed by Schneiter and Miller (1981). The GDD were calculated with the methodology proposed by the University of California (2017), adding up the daily values of mean temperature that were above the Tb (6.6 °C) using the following equation:

$$GDD = \frac{T_{\max} + T_{\min}}{2} - Tb$$

RESULTS AND DISCUSSION

Plant height and flower diameter were significantly greater in the sunflowers sowed on February 11, and although this species has ample climate adaptability (Balalić *et al*., 2012), the hybrid was affected by temperature (Baghdadi *et al*., 2014) in the first sowing. This coincides with that reported by Da Silva *et al*. (2018) in six cultivars of ornamental sunflower sown in the warm season; they showed an increase of 20.3%, 26.1%, 16.8%, and 18.6% in plant height, stalk diameter, number of leaves, and diameter of internal inflorescence, respectively, compared to the winter sowing (Table 1).

Growing degree-days

The Vincent Choice Dark Eye sunflower hybrid required 523 GDD to reach commercial maturity in the flower for the sowing date of January 31, and 476 GDD for the date of February 11 (Figure 3). The plants from both sowing dates showed slight variations in the GDD that were required for their development. Qadir *et al*. (2007) report that, under certain climate conditions, early sowings require more GDD when compared to the sowing windows that are used in the area.

Table 1. Plant height, flower diameter and number of leaves of sunflower 'Vincent Choice Dark Eye' for cut flower on two sowing dates.

Sowign date	Plant height (cm)	Flower diameter (cm)	Number leaves
January 31	47.84b*	6.091b	13.69a
February 11	54.99a	8.013a	12.8a
SE	11.62	1.42	3.90

SE=Standard error. *The means of the columns followed by different letters are statistically different (Tukey, p≤0.05).

The cultivation cycle of ornamental sunflower was 62 days to reach commercial maturity for the sowing date of January 31, and 54 days for the second sowing date. According to Alberio *et al*. (2015), this is because later sowing dates accelerate the crop's development because higher temperatures occur during the vegetative stage (Table 2). The data from the calculated GDD serve as a reference for scheduling sowing dates of the Vincent Choice Dark Eye sunflower hybrid, under conditions similar to those described in this study.

Pest control

Sunflower cultivation resulted in few weeds; however, pests such as the whitefly (*Bemisia tabaco*, Figure 4a),

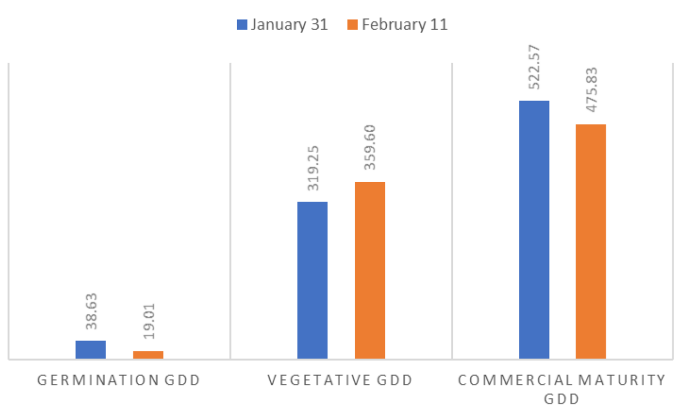

Figure 3. Cumulative degrees-days of development (GDD) in the germination, vegetative and commercial maturity stage that Vincent Choice Dark Eye requires for cut flower of two sowing dates.

Table 2. Phenological stages of sunflower 'Vincent Choice Dark Eye' for cut flower on two sowing dates.

Sowign date	Germination (Days)	Vegetative (Days)	Commercial maturity (Days)
January 31	5	41	62
February 11	3	43	54

the cabbage looper worm (*Trichoplusia ni*, Figure 4b), and the leaf miner fly (*Liriomyza* sp., Figure 4c and 4d) were present. To control whiteflies, three weekly application of Roma® detergent at 3% were carried out.

The cabbage looper worm is a voracious pest that can consume up to three times its own weight daily. The leaf miner flies create tunnels in the leaves. Damage from the pests results in poor and delayed plant development, which compromised its commercial value. Control of the leaf miner and cabbage looper was done through monitoring and manual control, which was a highly efficient practice at lowering the incidence of both pests.

Flowering stage

Flowering is induced by water stress, without modifying temperature and light conditions (Florido and Bao, 2014). In the January 31 sowing, when the sunflowers reached commercial height, irrigation was reduced by 30% to induce flowering (Figure 5).

Commercialization

As part of the study, before beginning the sunflower cultivation, local commercial prices were scouted. In the Texcoco market, the price of ten sunflowers was $45.00 MX (US$2.00). In wholesale markets, ten ornamental sunflowers with similar characteristics to the Vincent Choice were priced at $40.00 MX (US$1.7). However, at the dates of sale, the price was $10.00 MX per ten sunflowers (US$0.40). The strategies used to raise the sale price was to give added value with wrappings and colored ribbons that showcased the sunflowers' color, reaching a price of $50.00 MX (US$2.20) per ten (Figure 6).

Figure 6. Commercial presentation of the sunflower cut flower.

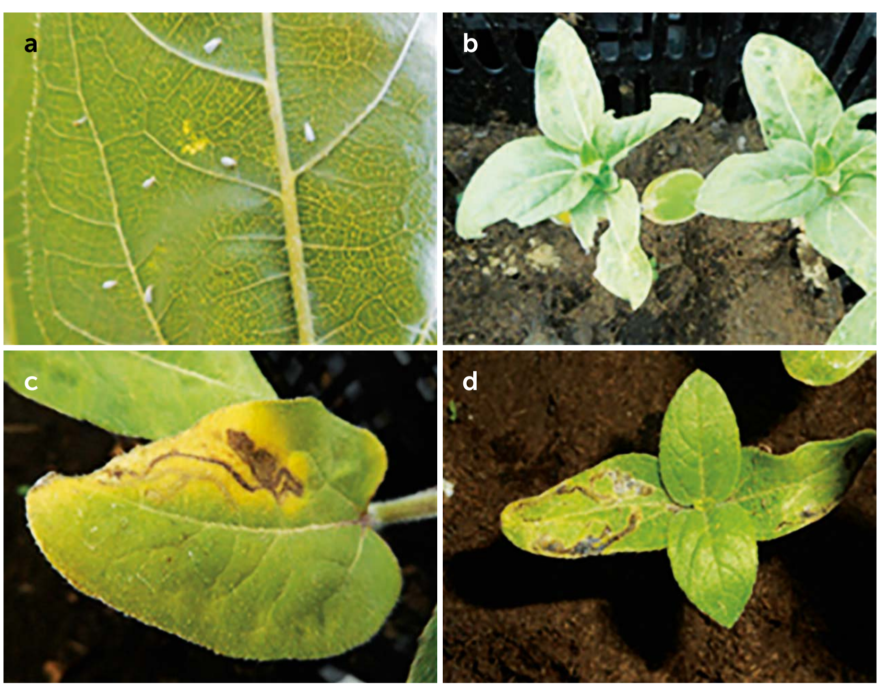

Figure 4. Damage caused by pests on sunflower: (a) white fly, (b) cutworm, (c) and (d) leafminers.

Figure 5. Sunflower cut point 'Vincent Choice Dark Eye'

This study calculated the costs and profits of cultivating 40 bouquets with ten cut flowers, with a price of $50.00 MX (US$2.20) per bouquet, considering a scenario of 100% successful sales (Table 3).

The substrate represented 7% of production costs, but this can be reutilized after disinfecting. The experiment demonstrated an estimation of costs and profits generated in the production and commercialization of cutting sunflowers, resulting in 28% earnings of gross profit (without cash flow analysis). The production and commercialization of ornamentals is considered to be a profitable business for producers, as long as good production practices are used. Nonetheless, costs should be adjusted for a real commercial production system.

Table 3. Production costs in sunflower for cut flower.

Concept	Cost ($)
Black plastic nursery crates (12 boxes) 5-year depreciation	888.00/5=177.00
Sunflower seed Vincent Choice Dark Eye	461.70
Peat moss ($700×170 L)	107.00
Triple fertilizer 18 (1 kg)	29.00
Detergent Roma	5.00
Korean paper	121.50
Colored ribbon	90.00
Labor cultivation, cutting and packaging (24 h)	450.00
Grand total	1441.2
Gross unit=bundle of sunflowers for sale 40×$50.00	2,000.00
Net Unit (Profit)	558.80
Cost benefit ratio	1.38

Source: Own elaboration.

CONCLUSIONS

At a planting density of 153 plants m^{-2}, the quality of the cutting flowers is maintained. Late sowing increased the height and diameter of the flower. For the sowing date of January 31, the sunflower hybrid required 523 GDD to reach cutting point, and 476 GDD for February 11. The commercialization of sunflower benefitted from the added value, as this increased its market price fivefold.

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REFERENCES

Alba, A., & Llanos, M. (1990). El cultivo del girasol. Madrid, España: Mundi-Prensa.

Alberio, C., Izquierdo, N. G., & Aguirrezábal, L. A. N. (2015). Sunflower Crop Physiology and Agronomy. En Martínez-Force, E., Dunford, N. T., y Salas, J. J. (Eds.), Sunflower (pp. 53-91). Urbana, E.U.: AOCS Press. doi: 10.1016/B978-1-893997-94-3.50009-X

Andrew, R. L., Kane, N. C., Baute, G. J., Grassa, C. J., & Rieseberg, L. H. (2013). Recent nonhybrid origin of sunflower ecotypes in a novel habitat. Molecular Ecology, 22(3), 799-813. doi: 10.1111/mec.12038

Baghdadi, A., Halim, M., Nasiri, A., Ahmad, I., & Aslani, F. (2014). Influence of plant spacing and sowing time on yield of sunflower (*Helianthus annuus* L.). Journal of Food Agriculture and Environment, 12(2), 688-691. Recuperado de https://www.researchgate.net/publication/263279191_Influence_of_plant_spacing_and_sowing_time_on_yield_of_sunflower_Helianthus_annuus_L

Balalić, I., Zorić, M., Brankovic, G., Terzić, S., & Crnobarac, J. (2012). Interpretation of hybrid × sowing date interaction for oil content and oil yield in sunflower. Field Crops Research, 137, 70-77. doi: 10.1016/j.fcr.2012.08.005

Bye, R., Linares, E., & Lentz, D. L. (2009). México: Centro de origen de la domesticación del girasol. TIP Revista Especializada en Ciencias Químico-Biológicas, 12(1), 5–12. Recuperado de http://www.scielo.org.mx/pdf/tip/v12n1/1405-888X-tip-12-01-5.pdf

Da Silva, S., Beckmann, M., de Souza, G., de Oliveira, T., Lima, G., & Chaves, A. (2018). Growth of ornamental sunflowers in two growing seasons under semiarid conditions. Emirates Journal of Food and Agriculture, 30(5), 381-388. doi: 10.9755/ejfa.2018.v30.i5.1681

Escalante-Estrada, J. A. S., Rodríguez-González, M. T., & Escalante-Estrada, Y. I. (2015). Acumulación y distribución de materia seca en cultivares de maíz asociados con frijol en clima templado. Revista Mexicana de Ciencias Agrícolas, 1, 139-143. Recuperado de https://www.redalyc.org/pdf/2631/263139243021.pdf

Florido, B. M., & Bao, F. L. (2014). Tolerancia a estrés por déficit hídrico en tomate (*Solanum lycopersicum* L.). Cultivos Tropicales, 35(3), 70–88. Recuperado de http://scielo.sld.cu/pdf/ctr/v35n3/ctr08314.pdf

Hammer, G., Goyne, P., & Woodruff, D. (1982). Phenology of sunflower cultivars. III. Models for prediction in field environments. Australian Journal of Agricultural Research, 33(2), 263- 274. doi: 10.1071/AR9820263

Qadir, G., Malik, M. A., & Hassan, F. U. (2007). Growing Degree Days and Yield Relationship in Sunflower (*Helianthus annuus* L.). International Journal of Agriculture & Biology, 9(4), 564-568. Recuperado de http://www.fspublishers.org/published_papers/65304_..pdf

Schneiter, A. A., & Miller, J. F. (1981). Description of Sunflower Growth Stages. Crop Science, 21(6), 901-903. doi: 10.2135/cropsci1981.0011183X002100060024x

Servicio de Información Agroalimentaria y Pesquera. (2018). Anuario Estadístico de la Producción Agrícola. https://nube.siap.gob.mx/cierreagricola/

Universidad de California. (2017). Metodología para el cálculo de Unidades de Calor diseñada por la University of California, Agriculture and Natural Resourses, empleada en el SIMARBC. http://www.simarbc.gob.mx/descargas/metodologiauc.pdf

Vera-Montenegro, L., & Chavarría, P. J. (2010). Híbridos de girasol ornamental sometidos a diferentes densidades de siembra.

Espamciencia, 1(2), 60-64. Recuperado de https://www.researchgate.net/publication/279897963_HIBRIDOS_DE_GIRASOL_ORNAMENTAL_SOMETIDOS_A_DIFERENTES_DENSIDADES_DE_SIEMBRA

Zamudio, F. & Alvarado, A. (1994). Análisis de diseños experimentales con igual número de submuestras. Chapingo, México: Universidad Autónoma Chapingo.

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Digital Images Analysis on a Mobile Device to Estimate Surface Area and Volume of Mango Fruit (*Mangifera indica* L.)

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ABSTRACT

Objective: To develop a technique based on the partition method, to estimate the surface area and volume of mango fruit (*Mangifera indica* L. cv. "Ataulfo") using two digital orthogonal images, obtained and processed on a mobile device with the Android® operating system, segmented by different discriminants.

Design/Methodology/Approach: A technique was developed to estimate the surface area and volume of "Ataulfo" mango fruit based on digital images and was implemented directly on a smartphone with the Android® operating system. Three discriminants were evaluated for segmentation (red channel, green channel, and HIS color intensity) and applied in n=30 fruit. The precision and accuracy of the technique was determined.

Results: The surface area and volume of the fruit when estimated using the red channel presented a coefficient of variation of less than 2.0% in both variables and the estimation error was less than 3% for surface area and less than 5% for volume.

Study Limitations/Implications: This technique was limited to fruit with an elliptical cross-section and smooth surface.

Findings/Conclusions: The proposed technique is a non-destructive alternative to estimate the surface area and volume of "Ataulfo" mango fruit with a reasonable margin of error and can be implemented directly on an Android® device using only the red channel as a segmentation discriminant.

Key words: Android®, elliptical frustum, segmentation, smartphone.

INTRODUCTION

Mango (*Mangifera indica* L.) is a tropical crop of global importance. Mexico is the number one exporter and produces more than 50 cultivars. One of these is "Ataulfo", whose organoleptic and nutritional characteristics make it acceptable for the international market (Palafox-Carlos *et al*., 2012; Sáyago-Ayerdi *et al*., 2013).

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The size of horticultural products, in addition to being a variable for quality, affects physical properties such as surface area and volume. These properties are necessary for the study of physiological processes such as phenomena related to gas permeability, transpiration, and cooling (Goñi *et al*., 2007; Valle-Guadarrama *et al*., 2009).

The analysis of digital images has made possible the development of non-destructive methods for estimating surface area and volume of horticultural products. The best results were found with the use of a 3D scanner (Uyar and Erdogdu, 2009; Kelkar *et al*., 2011), infrared sensors (Wang and Li, 2014), and commercial software for computer-aided design (Goñi *et al*., 2007).

One alternative is the use of systems that only require a digital camera and a processing unit (Saltani *et al*., 2011). However, these systems have been applied in products with a regular shape such as: citrus, watermelon, melon or egg (Koc, 2007; Fellegari and Navid, 2011). In mango fruit, weight has been correlated to the sizes measured directly in digital images (Teoh and Syaifudin, 2007; Spreer and Müller, 2011). The availability of smartphones with cameras and a high processing capacity represents an alternative for estimating diverse variables such as: the color index and yield of citruses (Cubero *et al*., 2018) or the chlorophyll content (Vesali *et al*., 2017). Thus, it is possible to combine the analysis of digital images with the advantages of mobile devices to estimate the surface area and volume of "Ataulfo" mango fruit. For these reasons, the objective of this study was to develop a technique based on the partition method in order to estimate the surface area and volume of "Ataulfo" mango fruit using two orthogonal digital images obtained and processed on a mobile device with Android® operating system, segmented by different discriminants.

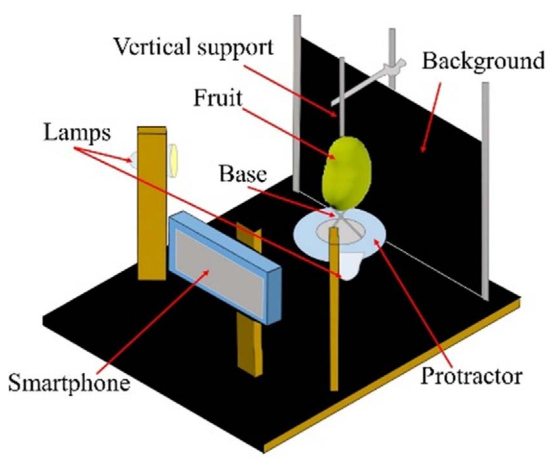

Figure 1. Image capturing system to estimate surface and volume of mango fruit.

MATERIALS AND METHODOLOGY

Plant material

This study was conducted in the Postharvest Physiology laboratory of Colegio de Postgraduados. Ripe mango (*Mangifera indica* L. cv "Ataulfo") fruit were used, acquired in the local market of Texcoco, Estado de México.

Capture conditions

Each fruit was placed on a revolving base, and two fluorescent lamps (28 W, 6500 K, D65 and 1747 lm, Promilight®, made in China) were placed 21.5 cm from the center of the fruit, angled at 45° against a black background. A smartphone (CellAllure Book2 model CAPHG28-01, Android® 4.4.2) was placed at 20.0 cm from the fruit to take a photo of the widest side of the fruit and another after turning it manually 90° (Figure 1).

Image capture method

The images were captured using the device's default photo application with the automatic settings, with a resolution of 640×480 pixels in the JPEG format at 24 bits. Each fruit was processed five times. In total, n=300 images were captured.

Preprocessing and grayscale image generation

A median filter with a 5×5 matrix was applied to the RGB images. Of the filtered images, three 8-bit images were generated in grayscale, based on: the red channel value (***RC***), the green channel value (***GC***), and the color intensity (***I***) of the HSI space (hue, saturation, and intensity) (Figure 2). The blue channel did not provide sufficient information for segmentation.

Segmentation of images in grayscale

The images were binarized using a local minimum (Gonzalez and Woods, 2007). Within the histogram, the local maximums were identified in the low intensity zone and in the high intensity zone. The threshold was determined as the local minimum between by the local maximums (Figure 3).

Analysis of digital images in grayscale

The grayscale images were processed and analyzed directly in the application for mobile devices, which was developed on Google's open source Android Studio 3.2.2 platform (Figure 4).

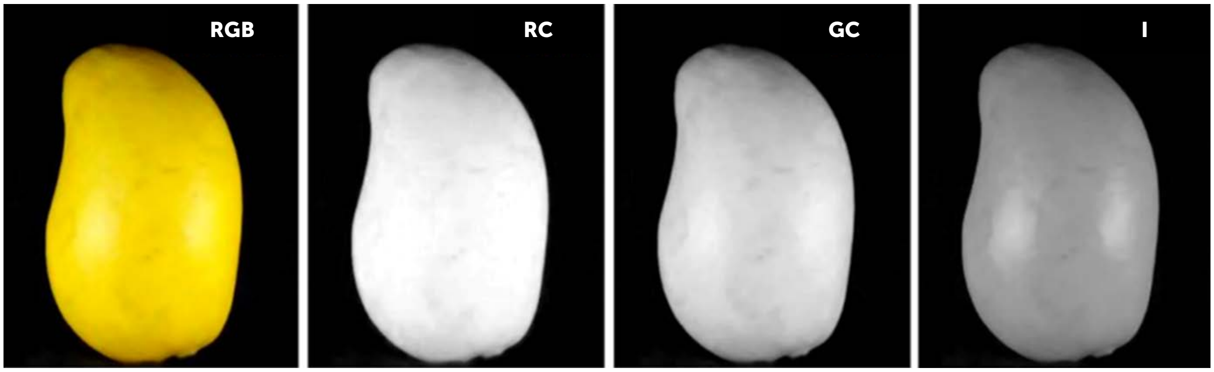

Figure 2. RGB image and grey scale images; red channel (RC), green channel (GC) and HSI color intensity (I).

Estimation of surface area and volume

The fruit was viewed as a group of elliptical frustums vertically overlapped and the lateral surface area and volume of each cone was estimated. According to Baldor *et al*. (1997), an elliptical frustum is characterized by the semi-major axis (*r*) and the semi-minor axis (*s*) in each of its bases, and its height (*h*). The values of *r* were obtained from the image taken at 0°, the *s* values were obtained from the image taken at 90° according to the number of pixels that corresponded to the fruit in each row, while *h* was kept constant at one pixel (Figure 5).

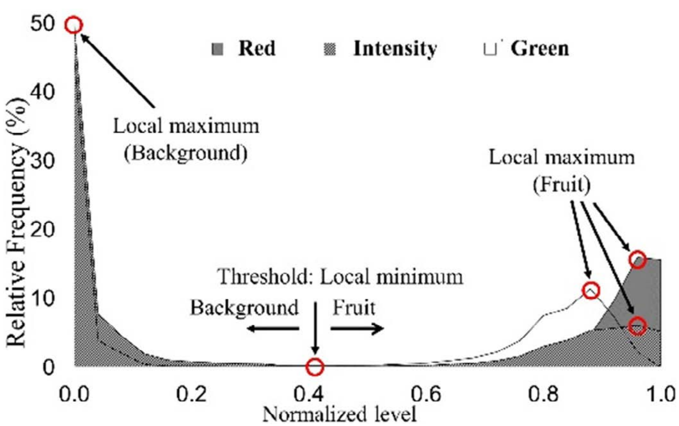

Figure 3. Histogram of the normalized values of the red channel, green channel, and HIS color intensity from the RGB image.

The surface area could be estimated using the sum of the lateral surface area of each cone, obtained as the mean perimeter of the bases multiplied by the generatrix (Equations 1 and 2) (Khojastehnazhand *et al*., 2009).

$$A_f = \frac{\pi}{2}\sum_{i=1}^{n-1}\left(r_i + s_i + r_{i+1} + s_{i+1}\right) * G_i$$

$$G_i = \left(h^2 + \left(\frac{r_i + s_i}{2} - \frac{r_{i+1} + s_{i+1}}{2}\right)^2\right)^{1/2}$$

Where i indicates the row of pixels at the base of the cone; n is the total pixel rows of the fruit; h is the cone height (1 *Px*); G_i is the generatrix; and A_f is the surface area of the fruit (Px^2). Following Khojastehnazhand et al. (2009), the fruit volume was estimated as the sum of the volume of each cone, calculated as the average of the surface area of the bases multiplied by the cone height (Equation 3).

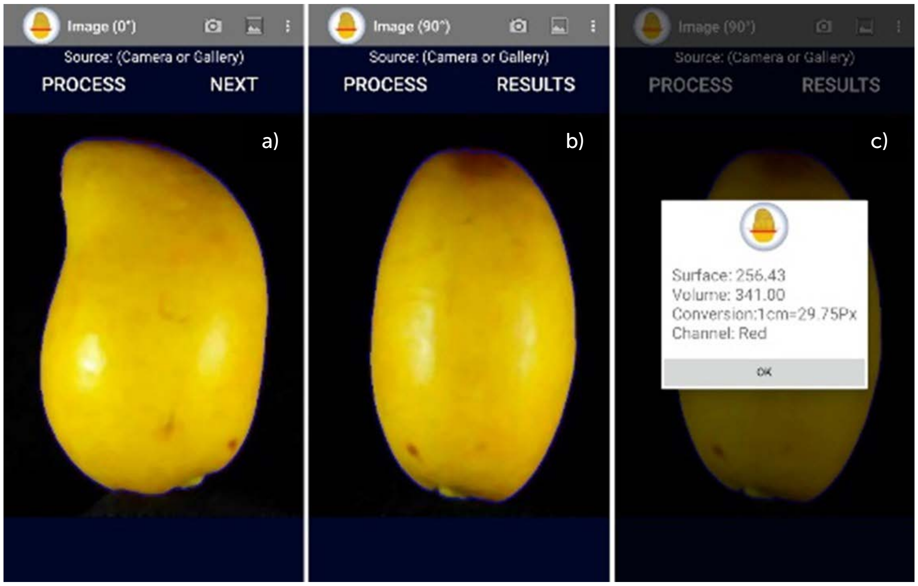

Figure 4. Android® application to estimate surface and volumen of mango fruit. a) and b) Contour identification on both fruit images (0° and 90°) and c) Results.

$$V_f = \frac{\pi}{2}\sum_{i=1}^{n-1}\left[\left(r_i * s_i\right) + \left(r_{i+1} * s_{i+1}\right)\right] * h$$

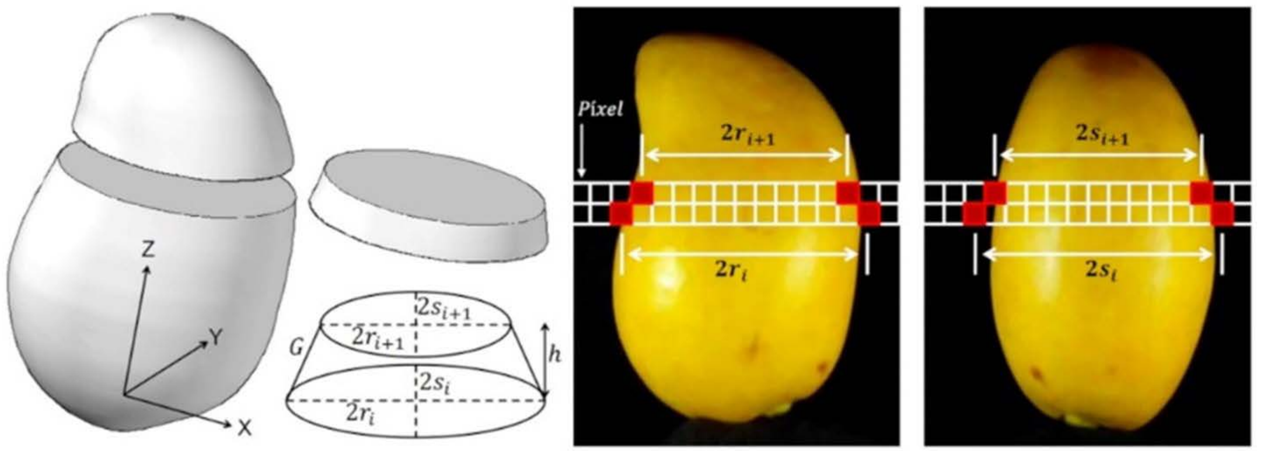

Figure 5. Mango fruit divided by elliptical frustums and variables of the frustum obtined from digital images.

Where *i* is the row of pixels where the cone's base was measured; *n* is the total pixel rows of the fruit; *h* is the height (1 *Px*); and V_f is the fruit volume, in Px^3.

Image calibration

A measuring stick was photographed in a vertical position, placed at the same distance as the fruit, and the spacing between the graduated marks was measured in the resulting image with the Image Tool 3.0 software (University of Texas Health Science Center at San Antonio). One pixel represented on average 0.0336 cm, and this value was used as a conversion factor to cm^2 and cm^3 for surface area and volume, respectively.

Measurement of reference surface area and volume of fruit

The fruit volume was measured using the water displacement method in a container (1200±1.75 mL). The fruit was placed inside the container, then 1000 mL of distilled water was added, previously measured in a 1000 mL volumetric flask, and the displaced liquid was collected using a 250 mL graduated cylinder.

To obtain the reference surface area, the pericarp was manually extracted from the fruit in vertical strips using a stainless-steel knife (Guillete®). The strips were digitalized with a scanner, model HP Scanjet 3770, and the surface area of each one was measured using the calibration technique (Figure 6).

Data analysis

The technique's precision was determined in terms of the mean coefficient of variation, and its accuracy as the mean relative error (Equation 4). In addition, a simple regression analysis (Equation 5) was carried out. The data were processed with R-Project® within the R-Studio® interface.

$$Err(\%) = \left| \frac{x_0 - x_1}{x_0} \right| * 100$$

where x_0 is the value measured using the reference method (cm^2 or cm^3); and x_1 is the value estimated using the digital images (cm^2 or cm^3).

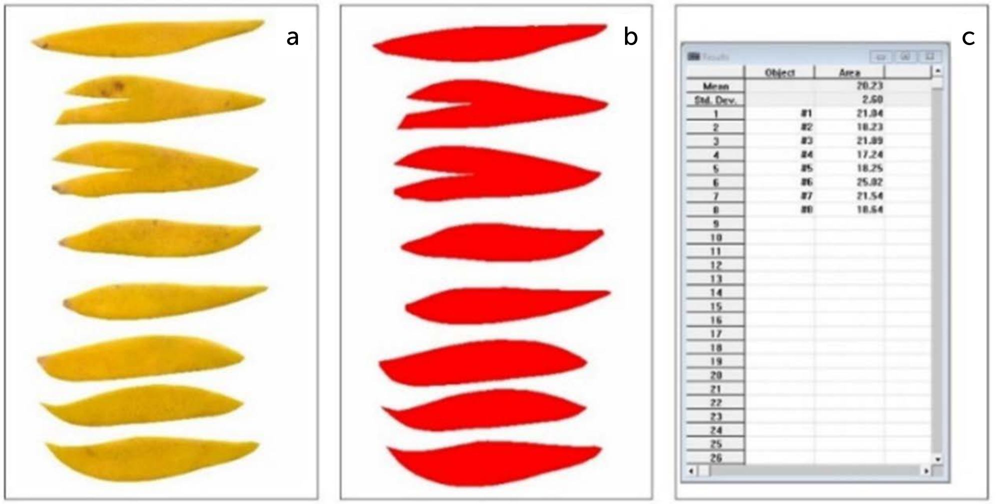

Figure 6. a) Mango fruit´s pericarp, b) segmented image y, c) individual surface

$$y = \beta_0 + \beta_1 * x + e$$

where y is the reference surface area or volume (cm^2 or cm^3); x is the surface area or volume of the fruit, estimated using the digital images; β_0 is the ordinate of the origin; β_1 is the slope; and e is the random error NIID (o, σ^2).

RESULTS AND DISCUSSION

Estimation of total surface area of the fruit

The surface area estimated using the digital images segmented using the red channel (***RC***) presented a lower standard deviation and coefficient of variation (3.07 cm^2 and 1.39%), while the greatest variation was found in the images segmented using color intensity (***I***) (Table 1). Sabliov *et al*. (2002) found lower values (0.32 cm^2) applying this method on spheres and lime fruit, but found higher values on lemon (3.7 cm^2) and peach (3.6 cm^2). This could possibly be due to the difficulty in placing the fruit in the same position.

In all cases, the fruit surface area was overestimated (Figure 7). However, the greatest accuracy was obtained from the images segmented using the red channel (***RC***), with a relative error of 2.19%, while the images segmented using color intensity (***I***) had 2.36% error; this rise in error could be caused by the blue channel, since it did not provide information individually for segmentation. Sabliov *et al*. (2002) attributed overestimation to the threshold method, and in this case, it can be attributed to the pericarp contracting after being removed from the fruit.

The estimation error was found in what was reported for other products such as eggs with 0.82% using a 3D scanner (Uyar and Erdogdu, 2009), limes with 2.95%, and peaches with 6.0% using image processing (Sabliov *et al*., 2002).

The determining coefficient was 0.97 in all cases (Table 1) and is close to the values reported for strawberry (0.96) using 30 digital images (Eifer *et al*., 2006), for banana (0.97) using a model that obtains geometric parameters from digital images, and orange (0.92) using two orthogonal images (Khojastehnazhand *et al*., 2009).

Estimation of fruit volume

The greatest accuracy in volume estimation was obtained from the images segmented using the red channel (***RC***) with a standard deviation of 4.88 cm^3 and a variation coefficient of 1.70%. These results are greater than those reported in spheres (0.07 cm^3), egg (4.0 cm^3), and lime (3.4 cm^3), but less than those reported in lemon (6.6 cm^3) and peach (4.8 cm^3) by Sabliov *et al*. (2002).

The volume obtained by this technique was underestimated by less than 5.0% (Table 2 and Figure 8). The error in volume estimation for diverse products was: 2.0% in apple (Goñi *et al*., 2007), 2.6% in mandaris (Khojastehnazhand *et al*., 2010), 3.5% in egg (Uyar and Erdogdu, 2009), 3.7% in onion (Wang and Li, 2014), 4.56% in cucumber, and up to 7.8% in watermelon (Koc, 2007).

The coefficient of determination (R^2) found in this study was 0.93 for the red channel (***RC***) and 0.94 for the other two discriminants. These values are similar to those

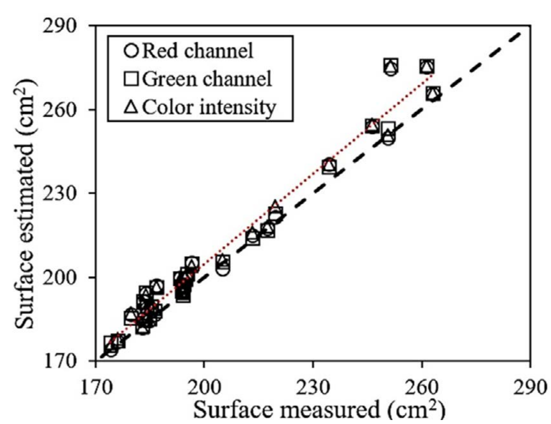

Figure 7. Surface of 'Ataulfo' mango fruit estimated by digital image analysis using different discriminants for segmentation.

Table 1. Surface of mango fruit estimated by digital image analysis. Standard deviation (*sd*), coefficient of variation (*C.V.*), relative error (*Err*), intercept (β_0), slope (β_1) and coefficient of determination (R^2).

Discriminant	*sd* (cm^2)	*C.V.* (%)	*Err* (|%|)	β_0 (P)	β_1 (P)	R^2
RC	3.07	1.39	2.19	14.57 (0.029)	0.91 (<0.001)	0.97
GC	3.34	1.50	2.32	14.95 (0.019)	0.91 (<0.001)	0.97
I	3.39	1.53	2.36	14.59 (0.019)	0.91 (<0.001)	0.97

Discriminant: *RC*: Red channel; *GC*: Green channel; *I*: HSI color intensity.

Table 2. Volume of mango fruit estimated by digital image analysis. Standard deviation (*sd*), coefficient of variation (*C.V.*), relative error (*Err*), intercept (β_0), slope (β_1) and coefficient of determination (R^2).

Discriminant	*sd* (cm^3)	*C.V.* (%)	*Err* (|%|)	β_0 (P)	β_1 (P)	R^2
RC	4.88	1.70	4.73	30.34 (0.013)	0.92 (<0.001)	0.93
GC	5.03	1.74	4.71	28.56 (0.019)	0.92 (<0.001)	0.94
I	4.95	1.73	4.72	29.46 (0.015)	0.92 (<0.001)	0.94

Discriminant: *RC*: Red channel; *GC*: Green channel; *I*: HSI color intensity.

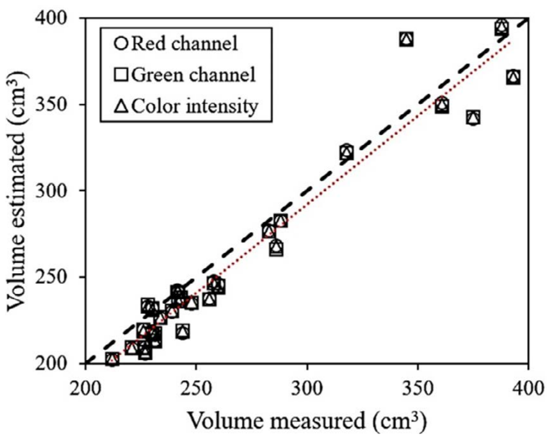

Figure 8. Volume of of 'Ataulfo' mango fruit estimated by digital image analysis using different discriminants for segmentation.

reported for mandarin (0.96) (Khojastehnazhand *et al*., 2010), orange (0.99) (Khojastehnazhand *et al*., 2009), onion (0.96 to 0.98) (Wang and Li, 2014), and apple (0.99) (Goñi *et al*., 2007).

CONCLUSION

The proposed technique in this study is a non-destructive alternative to estimate the surface area and volume of "Ataulfo" mango fruit with a reasonable error margin and can be implemented directly on an Android® device using the red channel as the only discriminant for segmentation.

REFERENCES

Baldor J. A., M. Santoló S. y P. E. Suardiaz C. (1997). Geometría Plana y del Espacio y Trigonometría. Publicaciones Cultural S.A. de C.V. México. 670 p.

Cubero, S., Albert F., Prats-Moltalbán J. M., Fernández-Pacheco D. G., Blasco J. and Aleixos N. (2018). Application for the estimation of the standard citrus colour index (CCI) using image processing in mobile devices. Biosysts. Engineering. 167:63-74.

Eifert, J. D., G. C. Sanglay, D. J. Lee, S. S. Sumner and M. D. Pierson. (2006). Prediction of raw produce surface area from weight measurement. J. Food Eng. 74(4):552-556.

Fellegari, R. and H. Navid. (2011). Determining the orange volume using image processing. Int. Conf. on Food Engineering and Biotechnology 9(2011):180-184.

Gonzalez, R. C. and E. Woods. (2007). Digital Image Processing. 3er Ed. Prentice Hall. USA. 954 p.

Goñi, S. M., E. Purlis and V. O. Salvadori. (2007). Three-dimensional reconstruction of irregular foodstuffs. J. Food Eng. 82(4):536-547.

Kelkar, S., S. Scott, C. Boushey and M. Okos. (2011). Developing novel 3D measurement techniques and prediction method for food density determination. Procedia Food Sci. 1:483-491.

Khojastehnazhand, M., M. Omid and A. Tabatabaeefar. (2009). Determination of orange volume and surface area using image processing technique. Int. Agrophys. 23:237-242.

Khojastehnazhand, M., M. Omid and A. Tabatabaeefar. (2010). Determination of tangerine volume using image processing methods. Int. J. Food Prop. 13(4):760-770.

Koc, A-B. (2007). Determination of watermelon volume using ellipsoid approximation and image processing. Postharvest Biol. Technol. 45(3):366-371.

Palafox-Carlos, H., E. M. Yahia and G. A. González-Aguilar. (2012). Identification and quantification of major phenolic compounds from mango (*Mangifera indica*, cv. Ataulfo) fruit by HPLC–DAD–MS/MS-ESI and their individual contribution to the antioxidant activity during ripening. Food Chemistry 135 (2012): 105-111.

Sabliov, C. M., D. Boldor, K. M. Keener and B. Farkas. (2002). Image processing method to determine surface area and volume of axi-symmetric agricultural products. Int. J. Food Prop. 5(3): 641-653.

Saltani, M., R. Alimardani and M. Omid. (2011). Modeling the main physical properties of banana fruit based on geometrical attributes. International Journal of Multidisciplinary Sciences and Engineering 2(2): 1-6.

Sáyago-Ayerdi, S. G., C. L. Moreno-Hernández, E. Montalvo-González, M. L. García-Magaña, M. Mata-Montes de Oca, J. L. Torres and J. Pérez-Jiménez. (2013). Mexican 'Ataulfo' mango (*Mangifera indica* L) as a source of hydrolyzable tannins. Analysis by MALDI-TOF/TOF MS. Food Research International 51 (2013): 188-194.

Spreer, W. and J. Müller. (2011). Estimating the mass of mango fruit (*Mangifera indica*, cv. Chok Anan) from its geometric dimensions by optical measurement. Comput. Electron. Agric 75(1): 125-131.

Teoh, C., and A. R. M. Syaifudin. (2007). Image processing and analysis techniques for estimating weight of Chokanan mangoes. J Trop Agric Food Sci 35(1):183-190.

Uyar, R. and F. Erdogdu. (2009). Potential use of 3-dimensional scanners for food process modeling. J. Food Eng. 93(3): 337-343.

Valle-Guadarrama, S., A. Gómez-Cruz, F. Cruz-Cruz y A. Chan-Chi. (2009). Modelado de una atmósfera modificada para conservar frutos de tomate de cáscara (*Physalis ixocarpa*). Ingeniería Agrícola y Biosistemas. 1(1): 33-38.

Vesali, F., M. Omid, H. Mobli and A. Kaleita. (2017). Feasibility of using smart phones to estimate chlorophyll content in corn plants. Photosynthetica. 55(4): 603-610.

Wang, W. and C. Li. (2014). Size estimation of sweet onions using consumer-grade RGB-depth sensor. J. Food Eng. 142(2014): 153-162.

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Route Analysis Through Filial Generations of Modern Varieties of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Objective: To measure the efficiency of using advanced generations of some commercial tomato hybrids for small farmers and to identify the most important yield components associated with yield.

Design/Methodology/Approach: Seven saladette-type hybrids of indeterminate growth were evaluated, as well as their respective generations F_2s and F_3s under greenhouse conditions. The evaluation of the three generations was carried out during the 2013 agricultural cycle. Three harvests were made at 82, 94 and 136 days after transplanting. The experiment was a randomized complete block design, with 4 replications and 10 plants per replication.

Results: Results indicated that there were significant differences for a few traits in F_2 and F_3. Path analysis showed that the total number of fruits had the highest direct and indirect effects on yield through generations.

Limitations of the study/implications: The usefulness of advanced generations of tomato commercial hybrids would depend on the genetic background of the parental lines that take part in such as hybrids, as some hybrids would present high inbreeding depression depending on the genetic composition of their progenitors.

Findings/Conclusions: Advanced generations of 'LORETO', 'CUAUHTÉMOC' and 'ESPARTACO' could be used by the small growers since low values of inbreeding depression were observed in F_2 and F_3 families.

Keywords: Inbreeding depression, production costs, path analysis, tomato breeding, farmers.

INTRODUCTION

In 2019, the principal countries producing tomatoes (*Solanum lycopersicum* L.) were China (31.8%), India (10.4%), United States (7.4%), Turkey (7.8 %), Egypt (4.5 %), Italy (3.6%), Iran (3.6%), Spain (2.6%), Brazil (2.4%) and Mexico (2.3%). The first three establish the global tendency in pricing and consumption (FAO, 2019). In Mexico, production grew at an average annual rate of 4.8% between 2006 and 2016 through the implementation of new technologies in commercial production systems, from open

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field farming to production in high-tech greenhouses with automated systems for irrigation, nutrition, phytosanitary control, and use of varieties with higher yield and resistance to diseases (FIRA, 2017). The Service for Agrifood and Fisheries Information (SIAP) in Mexico, reported that annual tomato production in 2018 was 3 780 950 tons with a yield of 76.83 t ha^{-1} (SIAP, 2019). Although it generates many jobs and high income for Mexican society, few government institutions work toward varietal development, which makes producers dependent on private transnational corporations to obtain germplasm (Martínez-Vázquez *et al*. 2016).

The high price of seeds forces small growers to use F_2 seeds from commercial hybrids to reduce costs, assuming that the yield and quality of the fruit will not be significantly affected in the next generations. Sahagún and Rodríguez (2011) point out that farmers should not plant the F_1 progeny because high heterogeneity and inbreeding depression have been observed in subsequent generations. In this regard, Poehlman and Allen (2003) observed that in autogamous species, segregation in the F_2 generation causes a reduction in yield per plant due to a high degree of heterozygosity in the population. In contrast, there is evidence of transgressive segregation in tomato (De Vicente and Tanksley 1993; Poehlman and Allen 2003; Shivaprasad *et al*. 2012), generating plants with larger fruit than their parents (Rodríguez *et al*. 2005) due to the positive or negative complementation of additive alleles, epistatic interactions of unique parental attributes, unmasking of recessive alleles form a heterozygous parent or any combination of these mechanisms (De los Reyes, 2019).

Charlesworth and Charlesworth (1987) suggest that inbreeding depression from endogamy in self-pollinating species is relatively low, since recurrent recessive deleterious alleles are eliminated. In this regard, it has been observed that the correlation in yield between F_1 and subsequent generations (F_2 and F_3) has not been well studied, and thus the effectiveness of using subsequent generations has not been defined. Therefore, the objectives of this study were to measure the efficiency of the use of advanced populations of some commercial tomato (*Solanum lycopersicum* L.) hybrids, and to identify the yield components that are most important for determining yield for commercial producers who will use them as selection indices.

MATERIALS AND METHODS

The tomato (*Solanum lycopersicum* L.) varieties evaluated were 'MOCTEZUMA', 'CUAUHTÉMOC', 'ESPARTACO', 'CID', 'SUN7705', 'LORETO' and 'RESERVA', of the Roma type and of indeterminate growth; as well as their respective F_2s and F_3s generations, under greenhouse conditions during three experimental cycles in Texcoco, Estado de México, Mexico (19° 30' N and 98° 53' W, and 2250 m altitude).

The evaluation of the three generations took place in the growing cycle of 2013. The seven F_1 hybrids and their F_2s and F_3s generations were sowed on March 22 of 2013 and transplanted on April 23 of 2013, in polyethylene bags (40×40 cm) filled with red tezontle (red volcanic rock) as a substrate. There were three harvests, at 82, 94 and 136 days after transplanting. The research was conducted under a randomized complete block experimental design, with four replicates and 10 individuals per replicate. Fertilization was carried out with a Steiner nutrient solution (Steiner 1984), the concentrations were modified according to the phenological stages and four irrigations per day were used during the growth cycle.

The phenotypic analysis consisted in the study of seven quantitative variables: total number of fruit per plant (TNF), yield per plant (YL) and average fruit weight (AFW) expressed in g, fruit diameter (FD) and fruit length (FL) expressed in mm, number of trusses per plant (NT), number of fruit per truss (NFT).

Specifically, for the TNF and the YL the total number of mature fruits for the three harvests was counted and weighed. The values of the fruit variables such as AFW, FD and FL, were obtained from a sample of five fruits from each plant per replicate (n=5).

The statistical analysis consisted of univariate analysis using the PROC GLM instruction in the statistical software SAS V9 (SAS Institute, 2002). Afterward, a means comparison was performed via the Tukey test (p=0,05). The inbreeding depression (DEP, in %) in F_2, was estimated with respect to F1 using $DEP=(F_1-F_2)/F_1$, while in F_3 the DEP was calculated on the average difference between the F_1 and F_3 generations, using $DEP=(F_1-F_3)/F_1$. In both estimates the final results were multiplied by -1 to indicate a decrease in the magnitude of the evaluated variable. Finally, a route analysis was carried out considering the total population of each variety according to the procedure described by Mcgiffen *et al*. (1994).

RESULTS AND DISCUSSION

The contrast analysis of the F_1 hybrid and its advanced generations is shown in Table 1. The majority of the F_1 genotypes showed insignificant differences compared to their advanced generations, which indicates that yield was statistically similar in F_2 and F_3 to that observed in F_1. By contrast, 'CID' and 'MOCTEZUMA' had significant differences for most of the variables. Magaña *et al*. (2013) and Hernández-Leal *et al*. (2013) studied the effect of inbreeding depression on modern varieties of tomatoes and discovered that some exhibited an inbreeding depression significant for yield and other yield-related characteristics, while other tomato varieties did not express this. Based on the data obtained, a tendency was observed that suggests that the degree of inbreeding depends to a large extent on the genotype or the variety, the environment, and the interaction of genotype by environment.

The percentages of inbreeding depression through the generations and the results of Tukey's test are presented in Table 2. Regarding YL, in general the values of inbreeding depression were higher in the F_2 generation than in F_3, where 'CID' ($F_{1:2}$=−45.3% and $F_{1:3}$=−47.2%), 'MOCTEZUMA' ($F_{1:2}$=−23.3% and $F_{1:3}$=−32.6%) and 'RESERVA' ($F_{1:2}$=−40.2%) exhibited significantly higher values. In this regard, Márquez (1988) points out that these differences in inbreeding depression through the generations are due to the different degrees of segregation in F_2. For TNF, the inbreeding values oscillated between −42.4 and 21.0%, where 'SUN7705', 'MOCTEZUMA' and 'CID' had the highest inbreeding depression values of the seven varieties. In NT, significant inbreeding depression was found in 'SUN7705'$F_{1:2}$,' MOCTEZUMA'$F_{1:3}$, 'RESERVA'$F_{1:2}$ and 'CID'$F_{1:3}$, with values of −17.8, −24, −16.3 and −29.4%, respectively. Quintana *et al*. (2010) observed increases in yield when a greater number of trusses were present.

The results of this study presented a similar pattern between yield and number of trusses, due to the negative effect on yield when the number of trusses decreased in F_2 and F_3.

Regarding the variables related to fruit size (AFW, FL and FD), the genotypes "RESERVA" and "CID" exhibited a significant inbreeding depression in these three traits. This similarity in inbreeding depression is because of the strong association present between fruit weight and fruit length and diameter (De Souza *et al*., 2012). Consequently, the results suggest that producers could use advanced generations of the 'LORETO' variety. On the other hand, "CUAUHTÉMOC" and "ESPARTACO" had a slight reduction through their generations, which suggests that the F_2 and F_3 generations could also be grown by small-scale farmers for commercial use.

Table 1. Mean squares of the orthogonal contrasts between the F_1 *vs*. F_2 and F_1 *vs*. F_3 in seven tomato varieties.

Varieties	YL	TNF	NT	NFT	AFW	FL	FD
'Sun 7705' *vs.* Sun 7705-F_2	91621.96	63.845*	1.08*	1.45	38.63	0.1861	0.0098
'Sun 7705' *vs.* Sun 7705-F_3	482947.92	68.56*	0.1596	0.1922	71.28	0.021	0.0265
'Loreto' *vs.* Loreto-F_2	3319.5	3.86	0.2016	0.2346	19.47	0.1405	0.0145
'Loreto' *vs.* Loreto-F_3	1.94	12.05	0.7938	7.76	244.65	0.0703	0.3042*
'Moctezuma' *vs.* Moctezuma-F_2	554615.12*	89.38*	0.9316	0.845*	120.51	0.045	0.005
'Moctezuma' *vs.* Moctezuma-F_3	1083995.60*	172.42**	2.92**	1.17*	18.21	0.005	0.012
'Cuauhtémoc' *vs.* Cuauhtémoc-F_2	139780.35	1.02	0.0091	4.21	229.52	0.2346	0.0265
'Cuauhtémoc' *vs.* Cuauhtémoc-F_3	999.05	20.0	0.7503	3.6	6.14	0.208	0.0666
'Reserva' *vs.* Reserva-F_2	1087222.58*	25.92	0.98*	0.72	634.39*	0.1275	0.8978**
'Reserva' *vs.* Reserva-F_3	478491.42	0.3281	0.0145	0.0025	485.32*	0.0221	0.3741*
'Espartaco' *vs.* Espartaco-F_2	407014	25.21	0.7626	0.0276	3.14	0.3698	0.0253
'Espartaco' *vs.* Espartaco-F_3	59726.59	6.75	0.0545	2.46	250.88	0.8581	0.1953
'Cid' *vs.* Cid-F_2	4228028.44**	320.05**	3.46	0.8911	1994.59**	0.1922	0.845**
'Cid' *vs.* Cid-F_3	4597421.65**	403.28**	4.70**	2.9	966.90*	3.58**	1.58**
CV (%)	25.69	18.73	11.79	15.62	13.06	8.49	6.22

*, ** Significant at $p \leq 0.05$ and 0.01, respectively. TNF=total number of fruits per plant; YL=yield per plant; NT=number of trusses per plant; NFT=number of fruits per truss; AFW=average fruit weight; FL=length of fruit; FD=fruit diameter.

Table 2. Phenotypic means and percentage reduction exhibited among tomato varieties throughout their generations.

Varieties	YL (g)	R (%)	TNF	R (%)	NT	R (%)	NFT	R (%)	AFW (g)	R (%)	FL (cm)	R (%)	FD (cm)	R (%)
SUN 7705	1870.4 a		23.6 a		4.5 a		7.3 a		113.2 a		5.5 a		4.0 a	
SUN 7705-F_2	1656.3 a	−11.5	18.0 b	−23.7*	3.7 b	−17.8*	6.4 a	−12.3	117.6 a	3.9	5.8 a	5.5	4.0 a	0
SUN 7705-F_3	1379.0 a	−26.3	17.8 b	−24.6*	4.2 ab	−6.7	7.6 a	4.1	107.2 a	−5.3	5.6 a	1.8	3.8 a	−5
LORETO	1815.6 a		20.0 b		4.1 a		7.2 a		124.4 a		5.4 a		4.2 a	
LORETO-F_2	12774.8 a	−2.3	21.4 ab	7	4.4 a	7.3	7.5 a	4.2	121.3 a	−2.5	5.1 a	−5.6	4.1 a	−2.4
LORETO-F_3	1816.6 a	0.1	22.5 a	12.5	4.7 a	14.6	9.1 a	26.4	113.4 a	−8.8	5.6 a	3.7	3.8 b	−9.5*
MOCTEZUMA	2261.7 a		27.9 a		5.0 a		8.1 a		118.0 a		5.6 a		3.9 a	
MOCTEZUMA-F_2	1735.1 b	−23.3*	21.2 b	−24*	4.3 ab	−14	7.5 b	−7.4*	110.3 a	−6.5	5.7 a	1.8	3.9 a	0
MOCTEZUMA-F_3	1525.5 c	−32.6*	18.9 b	−32.3**	3.8 b	−24*	7.4 b	−8.6*	115.0 a	−2.5	5.5 a	−1.8	4.0 a	2.6
CUAUHTEMOC	1457.9 a		15.3 a		3.2 a		6.4 b		111.9 a		5.6 a		3.9 a	
CUAUHTEMOC-F_2	1193.5 a	−18.1	16.0 a	4.6	3.1 a	−3.1	7.9 a	23.4	101.2 a	−9.6	5.2 a	−7.1	3.8 a	−2.6
CUAUHTEMOC- F_3	1435.6 a	−1.5	18.5 a	21	3.8 a	18.8	7.8 a	21.9	110.1 a	−1.6	5.9 a	5.4	3.7 a	−5.1
RESERVA	1835.5 a		21.3 a		4.3 a		7.3 a		106.2 a		5.4 a		3.9 a	
RESERVA-F_2	1098.2 b	−40.2*	17.7 a	−17	3.6 b	−16.3*	7.9 a	8.2	88.4 b	−16.7*	5.6 a	3.7	3.3 b	−15.4*
RESERVA-F_3	1346.4 ab	−26.7	20.9 a	−1.9	4.2 a	−2.3	7.3 a	0	90.7 b	−14.6*	5.5 a	1.9	3.5 b	−10.3*
ESPARTACO	2095.1 a		23.4 a		4.2 a		7.6 a		116.1 a		5.9 ab		3.9 a	
ESPARTACO-F_2	1644.0 a	−21.5	19.9 a	−15	3.5 a	−16.7	7.8 a	2.6	114.9 a	−1	5.4 b	−8.5	4.0 a	2.6
ESPARTACO-F_3	1922.3 a	−8.3	21.6 a	−7.7	4.0 a	−4.8	8.7 a	14.5	127.3 a	9.7	6.5 a	10.2	4.2 a	7.7
CID	3210.1 a		33.5 a		5.1 a		9.3 a		143.3 a		6.0 b		4.5 a	
CID-F_2	1756.2 b	−45.3**	20.9 b	−37.7**	3.9 ab	−23.5	8.6 a	−7.5	111.7 b	−22.1**	5.7 b	−5	3.8 b	−15.6**
CID-F_3	1694 b	−47.2**	19.3 b	−42.4**	3.6 b	−29.4**	8.1 a	−12.9	121.3 b	−15.4*	7.3 a	21.7**	3.6 b	−20**
LSD	1011.3		9.55		1.24		2.97		32.24		1.18		0.5768	

In the column, the means with the same letter between treatments are statistically equal (α=0.05); *, ** significant at p≤0.05 and 0.01, respectively; LSD=least significant difference. TNF=total number of fruits per plant; YL=yield per plant; NT=number of trusses per plant; NFT=number of fruits per truss; AFW=average fruit weight; FL=length of fruit; FD=fruit diameter, R=percentages of inbreeding depression.

The route analysis allows breeders to dissect the correlation coefficients in direct and indirect effects, and thus avoid erroneous conclusions about the components that truly present a significant effect on the yield (Mcgiffen *et al*., 1994). Table 3 shows that TNF had the greatest direct and indirect effects on the yield through the generations, with values between 0.78 and 0.81. Similar results were reported by Monamodi *et al*. (2013), who found that the number of fruits and the weight of a single fruit influenced the yield with direct effects of 0.752 and 0.446, respectively. Sharma and Verma (2000) reported that the total number of fruits per plant had the greatest direct effect on the yield. The above results indicate that the total number of fruits per plant is an important yield component, which is why this variable can be used as an indirect selection criterion suitable for identifying high yield specimens.

The route analysis of each genotype shows that TNF did not always exhibit the highest direct effect on yield, since AFW in "ESPARTACO", reached a high direct effect (0.66) on yield (Figure 1). In general, AFW was identified as an important trait that affects yield followed by the number of fruits per plant, with values that range from 0.22 to 0.35.

Diverse studies report similar values in terms of average weight per fruit, positively affecting yield in 0.46 and 0.96 (Mcgiffen *et al.,* 1994; Meena and Bahadur, 2015). Therefore these previous estimations are comparable to those obtained in the present study.

In NFT, the direct effects were not significant and had values lower than 0.03. These low direct effects found for NFT on yield in the combined analysis were also obtained in the single analysis within each genotype. The effect of NT on yield was negative in F_1 for almost all the genotypes except "CID" and "ESPARTACO". However, the magnitude of the direct effect exhibited by NT on yield was not constant throughout the generations, exhibiting a reduction in F_2 and an increase in F_3 for the 'CID' (0.27 and 0.36) and 'MOCTEZUMA' (0.03 and 0.10) varieties, while for F_2 and F_3 in the 'RESERVA' (0.43 and 0.33) and 'SUN 7705' (0.69 and 0.31) varieties, the observed effect was inverse to that found in the previous varieties. Previous studies suggest that the number of trusses per plant (NT) has a strong and positive effect on the yield (Supe *et al*., 1992; Rani *et al*., 2008). Such a result in the study can be explained by the indirect effect exhibited by the total number of fruits on the correlation coefficient formed by the number of trusses and the yield.

Table 3. Direct and indirect effects of the yield components obtained under the combined route analysis.

Variable *vs.* Yield	Generation	Direct effect	p	Indirect effect						r	P
				TNF	NT	NFT	AFW	FL	FD		
TNF	F_1	0.78	**	–	−0.11	0.01	0.21	0.02	0.00	0.90	**
	F_2	0.81	**	–	−0.02	0.00	0.08	0.00	0.03	0.90	**
	F_3	0.79	**	–	−0.05	−0.01	0.08	0.00	0.02	0.84	**
NT	F_1	−0.14	**	0.63	–	0.01	0.13	0.01	0.00	0.63	**
	F_2	−0.02	ns	0.62	–	0.00	0.05	0.00	0.03	0.67	**
	F_3	−0.07	ns	0.61	–	0.00	0.03	−0.01	0.02	0.58	**
NFT	F_1	0.02	ns	0.45	−0.06	–	0.15	0.01	0.00	0.57	**
	F_2	−0.01	ns	0.37	0.00	–	0.02	−0.01	0.01	0.38	**
	F_3	−0.02	ns	0.25	−0.01	–	0.07	0.00	0.01	0.30	**
AFW	F_1	0.35	**	0.46	−0.05	0.01	–	0.03	0.00	0.79	**
	F_2	0.22	**	0.29	−0.01	0.00	–	0.05	0.07	0.62	**
	F_3	0.34	**	0.19	−0.01	0.00	–	0.03	0.05	0.60	**
FL	F_1	0.04	ns	0.33	−0.03	0.01	0.26	–	0.00	0.60	**
	F_2	0.12	**	0.02	0.00	0.00	0.09	–	−0.01	0.21	**
	F_3	0.06	*	0.02	0.01	0.00	0.19	–	−0.01	0.27	**
FD	F_1	0.00	ns	0.41	−0.05	0.01	0.30	0.03	–	0.69	**
	F_2	0.10	ns	0.27	−0.01	0.00	0.15	−0.02	–	0.49	**
	F_3	0.07	*	0.23	−0.02	0.00	0.21	0.00	–	0.49	**

ns=not significant; *, ** significant at p≤0.05 and 0.01, respectively; p=significant; r=correlation coefficient; TNF=total number of fruits per plant; NT=number of trusses per plant; NFT=number of fruits per truss; AFW=average fruit weight; FL=length of fruit; FD=fruit diameter.

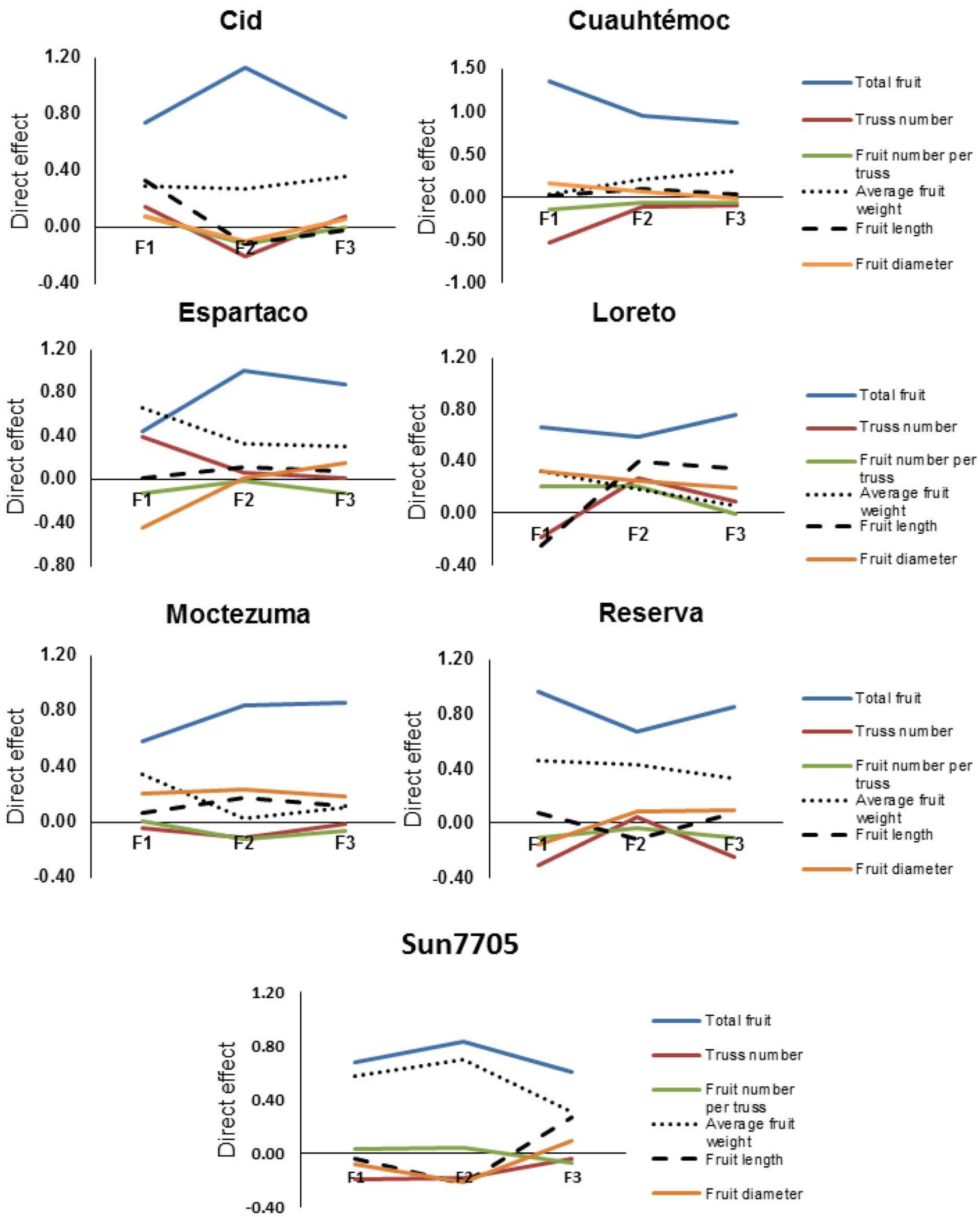

Figure 1. Direct effects of the six yield components evaluated in seven tomato genotypes.

The high direct and indirect effects of AFW and TNF across segregating generations found in most genotypes indicate that both traits can be used as a reliable indirect selection criterion to increase yield in populations consisting of 'CID', 'CUAUHTÉMOC', 'ESPARTACO', 'RESERVA' and 'SUN7705'.

CONCLUSIONS

Growers can use advanced generations of the 'LORETO' variety since the degree of segregation in F_2 and F_3 does not significantly differ from its parent. They can also use the 'CUAUHTÉMOC' and 'ESPARTACO' varieties because they presented low reduction in their productive behavior through their generations. Characteristics such as the total number of fruits and weight of fruit expressed higher direct effects on yield during the three generations, which indicates that these variables can be used as a reliable parameter for indirect selection to obtain high yield genotypes.

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REFERENCES

Charlesworth D. y Charlesworth B. 1987. Inbreeding depression and its evolutionary consequences. Annual Reviews Ecology Evolutionary Systematics. 18: 237-268.

De los Reyes G. B. 2019. Genomic and epigenomic bases of transgressive segregation – New breeding paradigm for novel plant phenotypes. Plant Science 288. 110213 1-10. DOI: https://doi.org/10.1016/j.plantsci.2019.110213

De Souza, L.M., Melo, P.C.T., Luders, R.R., y Melo, A.M. 2012. Correlations between yield and fruit quality characteristics of fresh market tomatoes. Horticultura Brasileira. 30(4): 627-631.

De Vicente, M.C. y Tanksley, S.D. 1993. QTL analysis of transgressive segregation in an interspecific tomato cross. Genetics. 134(2): 585-596.

FAO 2019. Available at: http://faostat.fao.org (accessed Feb13, 2020).

FIRA. 2017. Panorama Agroalimentario | Tomate Rojo 2017. 25 p.

Hernández Leal, E., R. Lobato Ortiz., J. J. García Zavala., D. Reyes-López., A. Méndez López., O. Bonilla Barrientos., y A. Hernández Bautista. 2013. Agronomic performance of F2 populations from tomato hybrids (*Solanum lycopersicum* L.). Revista Fitotecnia Mexicana, 36(3), 209-215.

Magaña Lira, N.A. Pena Lomelí. F. Sánchez del Castillo. J.E. Rodríguez Pérez., y E.D. Moreno Pérez. 2013. Productive performance of F_1 tomato hybrids and their F_2 populations. Revista Fitotecnia Mexicana, 36(4), 371-379.

Martínez Vázquez, E.D.L.Á., R. Lobato Ortiz., J. J García Zavala., y D. Reyes López. 2016. Heterosis in crosses among bell pepper-shaped Mexican native tomato (*Solanum lycopersicum* L.) lines and saladette type lines. Revista Fitotecnia Mexicana 39: 67-77.

Marquez, S.F. 1988: Plant Genotechnology. Editorial AGT, Distrito Federal, México.

McGiffen M.E. Pantone D.J. y Masiunas J.B. 1994. Path analysis of tomato yield components in relation to competition with black and eastern black nightshade. Journal of the American Society for Horticultural Science, 119(1): 6-11.

Meena O.P. y Bahadur V. 2015. Genetic association's analysis for fruit yield and its contributing traits of indeterminate tomato (*Solanum lycopersicum* L.) germplasm under open field condition. Journal of Agricultural Science, 7(3): 148-163.

Monamodi E.L. 2013. Analysis of fruit yield and its components in determinate tomato (*Lycopersicon lycopersci*) using correlation and path coefficient. Botswana Journal of Agriculture and Applied Sciences, 9(1):29-40

Poehlman J.M. y D.S. Allen. 2003: Genetic Improvement of Crops. Ed. Limusa, Distrito federal, México.

Quintana-Baquero R.A. H.E Balaguera-López. J.G. Álvarez-Herrera. J.F. Cárdenas-Hernández. y P. Hernando. 2010. The effect of number of clusters per plant on tomato (*Solanum lycopersicum* L.) yield. Revista Colombiana de Ciencias Hortícolas, 4(2): 199-209.

Rani C.I. D. Veeraragavathatham y S. Sanjutha. 2008. Studies on Correlation and Path Coefficient analysis on Yield Attributes in. Journal of Applied Sciences Research, 4(3): 287-295.

Rodríguez G. R., Pratta R. G., Zorzoli R & Picardi A. L. 2005. Transgressive segregation for fruit quality traits in a cross between exotic and mutant genotypes of *Lycopersicon*, New Zealand Journal of Crop and Horticultural Science, 33:4, 373-379, DOI: 10.1080/01140671.2005.9514373

Sahagún-Castellanos J. y J.E. Rodríguez-Pérez. 2011. Endogamia de sintéticos formados con líneas y cruzas simples. Revista Chapingo. Serie horticultura, 17(3): 107-115.

SAS INSTITUTE 2002: User´s Guide of SAS (Statistical Analysis System). SAS Institute Inc, Cary, North Carolina, U.S.A.

Sharma K.C. y S. Verma 2000. Path coefficient analysis in tomato (*Lycopersicom esculentum*). Indian J. Agr Sci. 70: 700-702.

Shivaprasad P. V., R. M. Dunn, B. A. C. M. Santos, A. Bassett y D. C. Baulcombe. 2012. Extraordinary transgressive phenotypes of hybrid tomato are influenced by epigenetics and small silencing RNAs. The EMBO J. 31:257-266.

SIAP. 2019. Producción Agropecuaria y Pesquera. Available at http://www.siap.gob.mx/ (accessed noviembre 2019).

Supe, V.S. y P.B. Kale. 1992. Correlation and path analysis in tomato. Journal-Maharashtra Agricultural Universities, 17: 331-331.

Steiner A.A. 1984. The universal nutrient solution. In: Proc. 6th International Congress on Soilless Culture. Wageningen. 633-650.

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Evaluation of fertilization of hydroponically cultivated castor bean (*Ricinus communis* L.)

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ABSTRACT

Objective: To determine the influence of fertilization on the growth and yield of five accessions of castor bean (*Ricinus communis* L.) cultivated in a hydroponic system.

Design/Methodology/Approach: Five outstanding accessions of the castor bean collection at COLPOS-Campus SLP were established: El Orito (EO), Encarnación de Díaz (ED), Salinas (SA), Ranchería de Guadalupe (RG) and San Luis (SL). The NPK (ppm) fertilization levels tested were: low (LL; 140, 50, 150), medium (ML; 210, 80, 250); high (HL; 280, 110, 350) and a control (NF; No fertilizer). The experimental design was a randomized block, with a 5×4 factorial arrangement (accession × fertilizer level).

Results: The differences in grain production were only significant (α=0.05) between the NF control (31 g plant^{-1}) and the three levels of fertilization (1103, 973 and 967 g plant^{-1}, for LL, ML, and HL, respectively, with no differences among them). Regarding accessions, no differences were observed among them, having ED the highest yield (681 g plant^{-1}). In the case of plant height, NF treatment reached 60 cm, while the other levels had an average height of 170 cm, with HL being the highest (180 cm). The highest oil content (38.4%) was obtained with the ML fertilization.

Study Limitations/Implications: The present study had no obvious limitations.

Findings/Conclusions: For seed yield, significant differences were found only between not fertilizing and fertilizing at any level. Between fertilized levels, however, the differences were not significant, as well as among accessions.

Keywords: yield, oil content, production systems, plant nutrition.

INTRODUCTION

In Mexico there are plant species with bioenergetic potential, among which the following stand out: Mexican pine nut (*Jatropha curcas* L.), castor bean (*Ricinus communis* L.), sweet sorghum (*Sorghum bicolor* (L.) Moench) (SAGARPA, 2017), and prickly pear cactus (*Opuntia* spp) (Amante *et al*., 2013), among others.

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Castor bean (*R. communis*) is a species of tropical origin, with a wide adaptation and distribution in the world. It is an important non-edible commercial oilseed crop that tolerates drought and has a good productive behavior in arid and semi-arid regions (Babita *et al*., 2010). Currently, it is used in the chemical industry known as ricinochemistry; the oil produced in its seed is the only one in nature that is soluble in alcohol, and also has a high density and viscosity. Castor bean seeds are a source of ricinoleic acid, which confers interesting industrial properties for the production of various products, including: inks, medicines, varnishes, synthetic polymers, hydraulic fluids, fuel additives, plastics, lubricants, cosmetics, low molecular weight aviation fuels, and biodiesel (Caupin, 1997; Beltrão *et al*., 2001; Comar *et al*., 2004; Velasco *et al*., 2005; Ogunniyi, 2006; Cardona *et al*., 2009). After detoxification, the seed residues can be used to produce animal feed supplements or as organic fertilizer (Jiménez *et al*., 2016).

According to Severino *et al*. (2006), castor bean is a demanding crop in terms of soil fertility, when high productivity is sought. In turn, Magalhães *et al*. (2002) mentioned that low potassium levels affect growth and vegetative reproduction, while the lack of micronutrients is mainly expressed in production. In general, there is limited information on castor bean responses to chemical fertilization with nitrogen, phosphorus and potassium (NPK). In this regard, Franklin *et al*. (2012) emphasize that an efficient fertilization program is required to generate high seed yields, which could allow determining the response curve in relation to the combination of N, P and K, for their adequate supply, in order to reduce the production costs.

The agricultural sector faces important challenges in the production of species for bioenergy purposes. In this sense, production systems that allow higher yields of raw material for use as biofuels must be sought; such is the case of hydroponic systems, where nutrients are dissolved in water to enter the plant more easily, making nutrition more efficient for plant growth, development, and yield.

Based on the above described, this study aims to determine the effect of different fertilization doses on growth, yield and oil content of five castor bean accessions grown in hydroponics.

MATERIALS AND METHODS

The study was conducted in the ejido Diego Martín (22° 43′ 50.6″ N, 101° 42′ 33.1″ W), municipality of Salinas, San Luis Potosí, with an approximate altitude of 2,038 m.a.s.l., a dry temperate climate, with mean annual temperature of 16 to 18 °C, and mean annual precipitation of 300 to 400 mm (INEGI, 2009).

Five outstanding castor bean accessions were used: El Orito (EO), from the state of Zacatecas; Encarnación de Díaz (ED), from Jalisco; and Salinas (SA), Ranchería de Guadalupe (RG) and San Luis (SL), from San Luis Potosí. These were established in an open-air hydroponics system, in pots with drip irrigation applied through drip tape lines (fertigation). Sowing was done in plastic containers with a mixture of sand:tezontle:compost (1:1:1), and transplanting to the hydroponics system took place two months later. Nutrient solution was applied using four irrigation heads, each connected to a 0.25 HP pump and a water tank, for each fertilization level used.

Eight irrigations were applied daily (from 10 to 20 minutes each) using an eight-time programmer (Steren model TEMP-08E®). To calculate the volume of water applied, four control drippers and eight drainage trays were installed to quantify the excess. Nutrient solutions, with increasing proportions of NPK, were: no-added fertilizer (NF), and low (LL), medium (ML) and high

Table 1. Nutrient solutions used for each fertilization level.

Fertilizer	Fertilization level (g/1000 L of water)		
	Low (LL)	Medium (ML)	High (HL)
Potassium nitrate	650	800	920
Calcium nitrate	550	750	820
Monoammonium phosphate *	250	310	430
Monopotassium phosphate **	250	310	430
Magnesium sulfate	120	120	120
Iron chelate	11	11	11
Copper sulfate	0.8	0.8	0.8
Zinc sulfate	0.7	0.7	0.7
Boric acid	1.8	1.8	1.8

* Used during vegetative growth. ** Used during seed filling.

(HL) fertilization levels, supplemented with secondary nutrients and micronutrients (Table 1). In order to support seed filling, the potassium concentration in the nutrient solution was increased after 100 DDT, when fruits began to ripen.

A randomized block experimental design was used, consisting of twenty treatments (five accessions and four fertilization levels) and three replications, for a total of n=60 experimental units, with a spacing of 1.5 m between plants and rows.

Between transplanting and 142 days after transplant (DAT), plant height, number of leaves and number of panicles, were evaluated eight times. At harvest time, dry matter production, grain yield, root volume, root dry weight, weight of 100 seeds, leaf area, and oil content were quantified. The last one was quantified using a Soxhlet 1050 oil extractor, following the technique proposed by Loredo *et al*. (2012). Statistical analysis consisted of analysis of variance (ANOVA) and means comparison using Tukey and LSD tests.

RESULTS AND DISCUSSION

Results obtained from the effect of fertilization on the variables evaluated in five accessions of *R. communis* are presented and discussed below.

Plant height

Ricinus communis accessions showed differential behavior with regard to plant height (Table 2). The SA accession presented the greatest height (179 cm), which was significantly different from the others. It was observed that SA and SL presented faster growth at the beginning of the cycle. The ED accession maintained growth until the end of the evaluation, while in the rest of the accessions growth ceased between 100 and 110 days DAT. This may indicate that ED is a plant with a later vegetative development. On the other hand, SL showed a reduction in height from 121 to 142 days DAT, with a loss of leaves, which could be related to this reduction in growth.

Regarding the fertilization levels tested (Table 2), it was observed that the differences in castor bean plant height at 142 DAT were less than 14 cm between the levels with fertilization. In this last evaluation, the addition of fertilizer increased height by more than 100% compared to the control (NF), although the difference was not significant between the three fertilization levels. After 60 DAT, *R. communis* showed the highest height values with the ML fertilization.

In this study, plant hight ranged from 1.27 to 1.79 m. Jiménez *et al*. (2015) and Salazar *et al*. (2014) report heights of 1.64 to 2.76 m for two accessions from Durango and two hybrids of castor bean. In another work, Solís *et al*. (2016) obtained plant heights from 0.68 to 1.11 m, for 11 varieties of castor bean and one unimproved collected seed, which were smaller than the ones found in this study.

As an example of the plant growth during the period evaluated, Figure 1 shows the height of the EO accession, depending on the fertilization levels. It can be seen that there were no significant differences

Table 2. Plant height (cm) by accession and fertilization level, along growth cycle (DAT).

DAT	Accession					Fertilization level			
	EO	ED	SA	RG	SL	NF	LL	ML	HL
0	15 a	14 a	27 a	17 a	24 a	13 a	13 a	14 a	14 a
22	22 b	23 b	36 a	21 b	34 a	27 a	26 a	27 a	28 a
39	53 c	56 c	75 a	51 c	64 b	36 b	64 b	68 ab	70 a
60	79 c	87 b	108 a	77 c	90 b	50 c	98 b	103 a	103 a
74	94 c	110 b	141 a	97 c	110 b	63 b	117 b	133 a	129 a
92	121 b	135 b	169 a	118 b	128 bc	76 b	152 a	156 a	151 a
106	126 c	143 b	180 a	121 c	131 c	78 b	164 a	162 a	157 a
121	130 c	149 b	179 a	124 c	149 b	78 c	164 ab	172 a	159 b
142	133 b	155 b	179 a	127 b	135 b	77 b	168 a	176 a	163 a

Means with different letters within the same sampling time (DAT) (for either Accession or Fertlization level) are statistically different (Tukey, $p \leq 0.5$). Accessions: EO = El Orito, ED = Encarnación de Díaz, SA = Salinas, RG = Ranchería de Guadalupe, SL = San Luis. Fertilization levels: NF = No fertilizer, LL = Low level, ML = Medium level, and HL = High level.

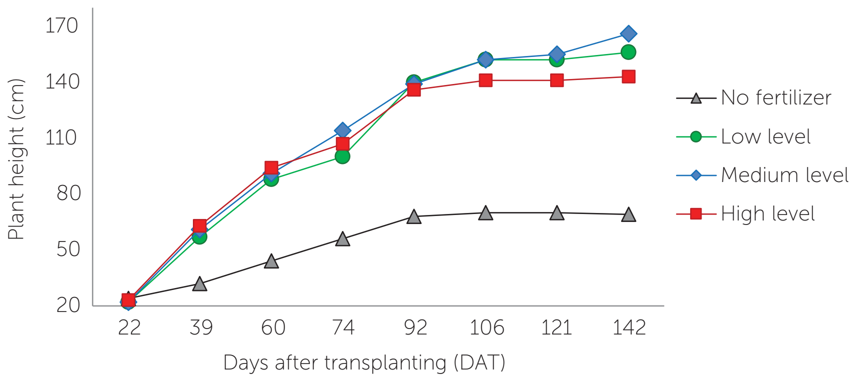


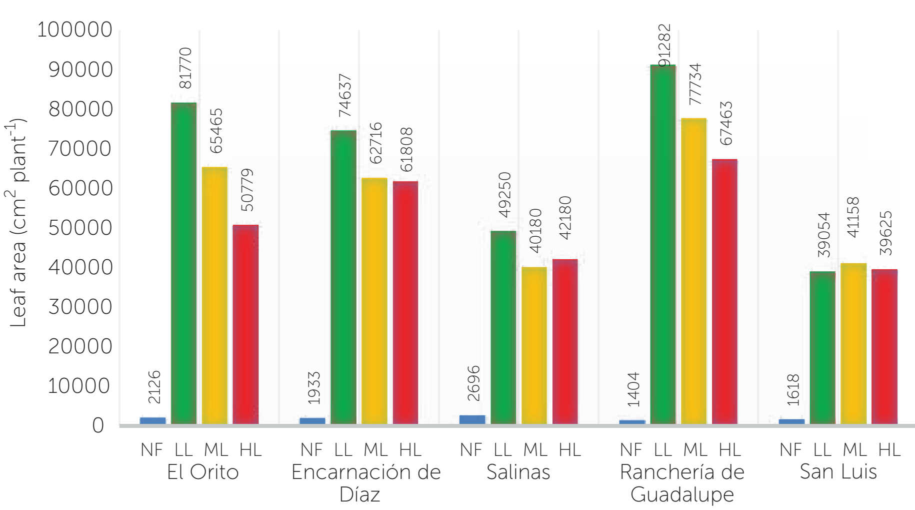
Figure 1. Plant height over time of EO accession in response to fertilization level.

between fertilization treatments, although the NM material presented the highest values, reaching 176 cm at 142 DAT. The NF level showed the lowest heights, registering a maximum value (78 cm) at 106 and 121 DAT. In all the fertilization treatments, similar height values were observed during the first 95 DAT. The same trend was present in the rest of the accessions. In this regard, Silva *et al*. (2003) observed significant differences in plant height at 100 DAT with the use of increasing doses of N (0, 30, 60 and 120 kg ha^{-1}), with 120 kg ha^{-1} being the best treatment.

Number of leaves

For the last evaluation (at 142 DAT), there were significant differences in the number of leaves per plant, both between the accessions and between the fertilization levels. The RG, ED and EO accessions showed the highest leaf production, with 203, 193 and 177 leaves, respectively, which were statistically different from those of SL (131) and SA (118). By fertilization level, there were only significant differences between the unfertilized level (16 leaves) and the low (226), medium (204) and high (204) levels; there were no differences among LL, ML, and HL of fertilization.

In the control treatment (NF), the behavior of the number of leaves (no fertilizer) was very peculiar, since it reached a maximum of 29 at 60 DAT, and decreased to 16 on the last evaluation (142 DAT). In the treatments with fertilization, the number of leaves always increased over time, reaching its highest value in the last evaluation. This result shows that castor bean requires fertilization, as suggested by Magalhães *et al*. (2002), Severino *et al*. (2006), and Franklin *et al*. (2012).



Fertilization levels: NF, No fertilizer; LL, Low level; ML, Medium level, HL, High level.

Figure 2. Leaf area accumulation in five castor bean accessions in response to fertilization levels.

Leaf area

Regarding leaf area (Figure 2), significant differences were observed between the accessions. The Tukey test formed three groups. In the first group, RG was the most productive, with an average of 59.471 cm^2 plant^{-1}; in the second group, EO and ED showed leaf areas of 50.034 and 50.273 cm^2 plant^{-1}, respectively. In the third group, with the lowest leaf area, SA and SLP had 33,577 and 30,364 cm^2 plant^{-1}, respectively.

There were also statistical differences among fertilization levels, and Tukey's test formed three groups: LL was in the first group, which showed the highest production, with 67,199 cm^2 plant^{-1}; in the second group, ML and HL accessions presents leaf areas of 57,450 and 52,371 cm^2 plant^{-1}, respectively. The NF level only produced an average of 1,956 cm^2 plant^{-1}.

Figure 2 shows the interaction of accessions with the fertilizer levels on leaf area production. In general, it was observed that fertilizers at ML and HL had a negative effect on leaf area, compared to LL. RG had the highest leaf area with LL fertilization; the EO accession with LL was the second highest producer. The NF treatment showed the lowest leaf area, producing only 5-10% compared to the fertilized levels (LL, ML and HL).

Fertilization levels: NF, No fertilizer; LL, Low level; ML, Medium level, HL, High level.

Table 3. Volume and dry weight of castor bean roots by accession and level of fertilization.

Accession	Root volume (mL plant^{-1})	Root dry weight (g plant^{-1})
El Orito (EO)	2831 bc	298 bc
Encarnación de Díaz (ED)	3505 ab	338 ab
Salinas (SL)	4146 a	405 a
Ranchería de Guadalupe (RG)	3013 bc	312 b
San Luis (SL)	2223 c	218 c
Fertilization level		
No fertilizer (NF)	993 b	67 b
Low level (LL)	3953 a	381 a
Medium level (ML)	3697 a	378 a
High level (HL)	3931 a	430 a

Means with different letters within a variable (for either Accession or Fertlization) are statistically different (Tukey, $p \leq 0.5$).

Root volume and dry weight

There were statistical differences in root volume and dry weight, both between accessions and between fertilization levels (Table 3). By accession, SA showed the greatest volume (4,146 mL plant^{-1}) and dry weight (405 g plant^{-1}), which were not different from those of ED; however both of them were different from the rest of the accessions. As for the level of fertilization, significant differences were only registered between the level without fertilization and those with fertilization for the two variables, with no differences among LL, ML, and HL. These results show that fertilizing castor bean, even at the low level, increases both root volume and root dry weight by about 3.9 and 5.7 times their values, respectively, with implications in the soil exploration area for access to moisture and nutrients.

Number of panicles

There were also significant differences in the number of panicles per plant, both between accessions and between fertilization levels. Among accessions, SL was the highest producer with 27 panicles, followed by ED with 25. The EO and RG accessions showed very similar numbers (18 and 19, respectively), while SA was the lowest producer, with 14 panicles.

Regarding fertilization levels, there were only significant differences between the level without fertilization (NF), with only 2 panicles, and those with fertilization, which presented 24, 27 and 29, with the LL, ML and HL levels, respectively.

Dry matter production

Regarding the dry matter produced (g plant^{-1}), at 142 DAT the highest production was registered in ED, with 841; on the other hand, the EO, SA, and RG accessions produced around 817, with differences of two grams between them. SL produced only 549 g plant^{-1}, being statistically different from the rest. It was observed that accessions showed different physical characteristics, such as very elongated and thick stems in SA, and EO, ED, and RG having more branches and leaves; even so, they had a similarity in terms of dry matter production.

There were no significant differences in dry matter production among LL, ML and HL fertilization levels (831.6, 831.6, 837.2 g plant^{-1}, respectively). However, when no fertilizer was applied, dry matter accumulation was only 32 g plant^{-1}. Thus, it is inferred that fertilizing castor bean, even at a low level, is required to increase dry matter production; in fact, in this study EO, ED and RG accessions produced the highest amount of dry matter with the LL treatment.

Grain yield

There were significant differences in grain yield only between the unfertilized level (31 g plant^{-1}) and the low, medium and high fertilization levels (1103, 973 and 967 g plant^{-1}, respectively), although between the latter three the differences were not significant. In addition, there were no significant differences in seed yield among accessions. ED was the most productive (681 g plant^{-1}), followed by RG, EO, SA and SL (661, 652, 539 and 530 g plant^{-1}, respectively). It was observed that SL was damaged by a severe wind event; some branches were broken, showing a weakness in their basal part, which is accentuated when green, hydrated and heavier panicles are present. This could have influenced yield, due to a possible loss of fruits.

Regarding grain yield per accession as a function of the fertilization level, Figure 3 shows a differentiated response of the accessions to fertilizer application, since some of them, such as EO and SA, reached the maximum yield with HL fertilization, while ED, RG and SL produced more grain with LL fertilization. This indicates that in some cases grain yield was affected as more fertilizer was applied; however, it is very evident that castor bean responds to fertilization, since even with the LL treatment grain yield increased more than 11 times, compared to the NF control level. This confirms what Severino *et al*. (2006) mentioned in relation to the fact that castor bean requires fertile soils in order to ensure high yields.

The results obtained in this study are similar to those obtained by Solís *et al*. (2016) with a seed collected in Estado de México and 10 varieties from Chiapas and Michoacán evaluated in soil, and reporting yields ranging from 0.3 to 1.1 kg plant^{-1}.

Seed oil concentration

The highest oil concentration in castor bean seeds was observed in the ED accession (37%), followed by SA and SL (both with 34%) and RG (33%), while EO had the lowest concentration (32%). With reference to fertilization, the NF and LL levels led to a 32% oil production, while the highest production was obtained with ML (38%), and the lowest with HL (31%). Figure 4 shows the percentage of oil by accession as a function of the fertilization level. The highest concentration was obtained with the SA accession fertilized at ML, followed by the ED accession with the ML and HL levels of fertilization. Something that stands out is that in the SL and EO accessions the highest concentration of oil in the seed was obtained without fertilization.

According to the data, the average castor oil yield with the NF level was 44 kg ha^{-1}, while with the LL, ML and HL levels, production values were 1,568, 1,643 and 919 kg ha^{-1}, respectively.

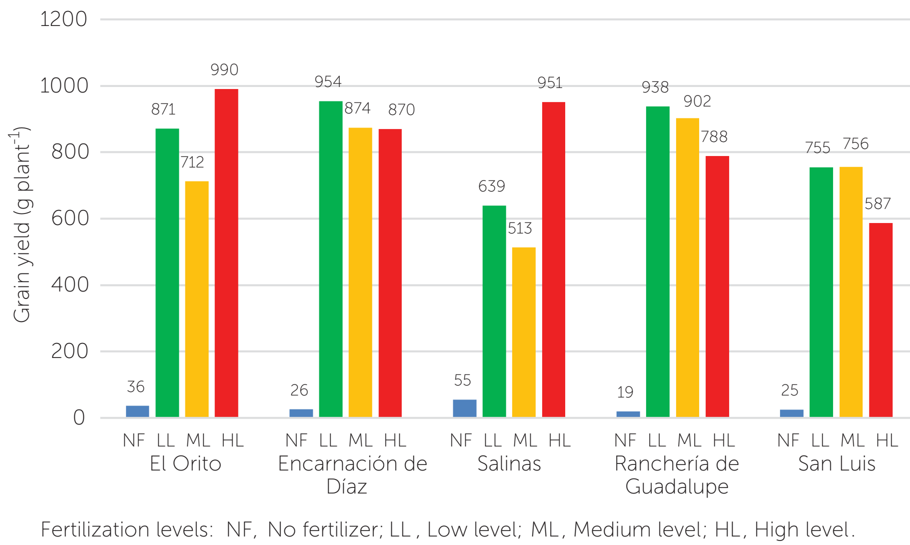


Figure 3. Seed yield of five castor bean accessions in response to fertilization level.

Oil concentration values in this study (28 to 52%) were higher than those reported by Salazar *et al*. (2014) and Jiménez *et al*. (2015), which ranged from 13.6 to 40.3% for seeds from Durango and some hybrids. Our values are within those reported by Goytia-Jiménez *et al*. (2011) for 151 materials from Chiapas, with oil concentrations ranging from 12.2 to 64.8%. In turn, Martínez *et al*. (2012) reported higher values (between 51.9 to 63.3%) for 10 castor bean varieties.

Weight of 100 seeds

The weights of 100 seeds of castor bean accessions evaluated are shown in Table 4. According to the data, three groups were formed (small, medium and large): small seeds were found in EO and RG (with a 100-seed weight of 9.8 and 13.2 g); the ED accession had medium-size seeds (between 30.2 and 32.5 g); and large seeds were harvested in SA and SL (between 31.7 and

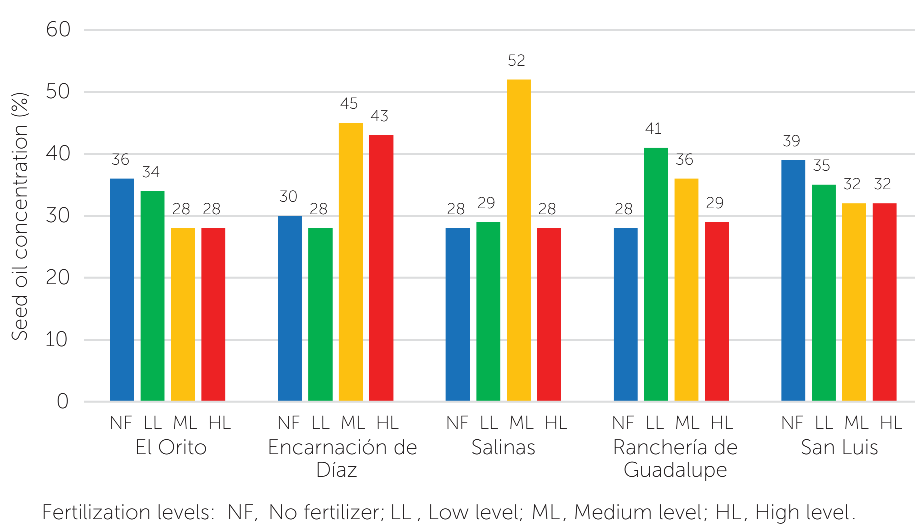


Figure 4. Seed oil concentration in five castor bean accessions in response to fertilization level.

Table 4. Weight of 100 seeds of five castor bean accessions grown under different fertilization levels.

Fertilization level	Accessions				
	EL Orito (EO)	Encarnación de Díaz (ED)	Salinas (SL)	Ranchería de Guadalupe (RG)	San Luis (SL)
No Fertilizer (NF)	10.6	30.2	40.3	9.8	31.7
Low level (LL)	13.2	32.0	60.5	12.0	46.3
Medium level (ML)	12.4	31.3	57.3	11.0	52.8
High level (HL)	11.7	32.5	53.5	12.0	52.5

60.5 g). Seeds from the SL accession showed more variation among the fertilization levels. Vasco (2014) evaluated the weight of 100 seeds and mentions that EO collection had an average weight of 11 g, ED 21.6 g, SL 52.9, and RG had a weight of 10.1; these values are somehow similar to the ones in this study.

CONCLUSIONS

Castor bean showed a significant response to fertilization, since even with the low level, it increased more than 11 times the grain yield compared to the control treatment. There were no differences among the fertilization levels (low, medium and high). The responses to fertilization were differentiated among accessions, with EO and SA showing the highest yield with HL, while ED and RG had the highest yield with LL. Seed yield per accession ranged from 530 to 681 g plant^{-1}, with no significant differences. The EO accession had the highest yield (990 g plant^{-1}), achieved with the LL of fertilization. ED (45%) and SA (52%) accessions were the highest oil producers, when grown with the LL fertilization. The accessions evaluated showed homogeneous plant heights, ranging from 140 to 180 cm. The RG accession had the highest number of leaves (203) and the largest leaf area (91,282 cm^2 plant^{-1}). SA produced 15 to 25% more roots than the other accessions.

The information reported here serves as a basis for accession management and for considering some traits for genetic breeding.

REFERENCES

Babita, M., Maheswari, M., Rao, L.M, Shanker, A.K., & Rao, D.G. (2010). Osmotic adjustment, drought tolerance and yield in castor (*Ricinus communis* L.) hybrids. Environ. Exp. Bot., 69, 243-249.

Beltrão, N.E.M., Silva, L.C., Vasconcelos, O.L., Azevedo, D.M., Vieira, D.J. (2001). Fitologia. En Pedrosa, D.M, & Lima, E. (Eds.). O agronegócio da mamona no Brasil (pp. 37-61). Campina Grande, Brasil: Embrapa.

Cardona, C.A., Orrego, C.E., Gutiérrez, L.F. (2009). La higuerilla: una alternativa agroindustrial. Manizales, Colombia: Artes Gráficas Tizán.

Caupin, H.J. (1997). Products from castor oil: past, present, and future. En F.D. Gunstone, & F.B. Padley (Eds.), Lipid Technologies and Applications (pp. 787-795). New York, USA: Marcel Dekker.

Comar, V., Tilley, D., Felix, E., Turdera, M., & Neto, M.C. (june of 2004). Comparative emergy evaluation of castor bean (*Ricinus communis*) production systems in Brazil and the US. En Ortega, E., & Ulgiati, S. (Editors), Advances in Energy Studies. IV Biennial International Workshop, Unicamp, Campinas, SP, Brazil.

Franklin, D.M.E., Garófalo, C.L.H., Carvallo, G.H.O., & Dantas, D.L.R. (2012). Crescimento e produção de duas cultivares de mamoneira sob fertilização NPK. Revista Caatinga, Mossoró 25(2), 35-43.

Goytia, J.M.A., Gallegos, G.R., Gallegos, C.R., Barrales, D.S., Zarate, B.R., Macías, C.U.A., Jiménez, R.E., Benigno, C.P., Vázquez, R.J., García, G.O., Méndez, F.E.I., & Nolasco, J.U. (2015). Paquete tecnológico para la producción de higuerilla (*Ricinus communis* L.) en Valles Centrales de Oaxaca. Chapingo, Texcoco, Edo. de México: Universidad Autónoma Chapingo.

INEGI. (2009). Prontuario de información geográfica municipal de los Estados Unidos Mexicanos. Salinas, San Luis Potosí. Recuperado de https://www.inegi.org.mx/contenidos/app/mexicocifras/datos_geograficos/24/24025.pdf

Jiménez, O.R., Rosales, S.R., Galindo, V.C.F., Jiménez, R.R., y Domínguez, M.P.A. (2015). Rendimiento de variedades e híbridos de higuerilla cultivados en diferentes ambientes de Durango, México. Agrofaz 15(1), 135-146.

Jiménez, O.R., Rosales, S.R., y Domínguez, M.P.A. (Coordinadores). 2016. Estrategias para el uso integral de la higuerilla en México. Durango, Dgo., México. SAGARPA-INIFAP-CIRNOC.

Loredo-Dávila, S., Espinosa-Hernández, V., Goytia-Jiménez, M.A., Diaz-Ballote, L., Soto-Hernández, R.M., & Marrone, P.G. (2012). Fatty acid methyl ester profile from lupinus in the identification of sweet and bitter species from this gender with oil of *Lupinus uncinatus* Schlecht seeds. Journal of Nutrition & Food Sciences 2:158. doi: 10.4172/2155-9600.1000158

Magalhães, R.T., Oliveira, I.P., Kliemann, H.J. (2002). Relações da produção de massa seca e as quantidades de nutrientes exportados por *Brachiaria brizantha* em solos sob o manejo pelo sistema "barreirão". Pesquisa Agropecuária Tropical, 32, 13-20. doi: 10.5216/pat.v32i1.2435

Martínez, V.B.B., Hernández, C.M., Solís, B.J.L., y Zamarripa, C.A. (julio de 2012). Calidad agroindustrial del aceite de higuerilla (*Ricinus communis* L.) para la producción de bioenergéticos en México. En Miranda, R.M.A. (Presidente), Desafios e oportunidades. V Congresso Brasileiro de Mamona / II Simpósio Internacional de Oleaginosas Energéticas & I Fórum Capixaba de Piñhao Manso, Campina Grande, Brasil.

Méndez-Gallegos, S.J., Rössel, D., Amante-Orozco, A., Gómez-González, A., y García-Herrera, J. (2010). El nopal en la producción de biocombustibles. Revista Salud Pública y Nutrición, Edición especial No. 5-2010, 70-84.

Ogunniyi, D.S. (2006). Castor oil: A vital industrial raw material. Bioresource Technology 97(9), 1086-1091.

SAGARPA. (2017). Bioenergéticos mexicanos: Higuerilla, *Jatropha curcas*, Sorgo dulce. Planeación Agrícola Nacional 2017-2030. Recuperado de https://www.gob.mx/cms/uploads/attachment/file/257070/Potencial-Bioenerg_ticos.pdf

Salazar, S.L.M., Rosales, S.R., Jiménez, O.R., Ríos, S.J.C., y Breton, V.B.A. (2014). Rendimiento de la higuerilla (*Ricinus communis* L.) cultivada en dos densidades de población en Durango, México. Agrofaz 14(1), 129-135.

Severino, M.I.L., Silva, V.A., Farias, N.E., Beltrão, M., & Cardoso, G.D. (2006). Sexual expression of castor influenced by fertilizer and mepiquat chloride. Rev. Ciên. Agron, 37, 339–344.

Silva, J.V., Lacerda, C.F., Costa, P.H.A., Enéas, F.J., Gomes, F.E., & Prisco, J.T. (2003). Physiological responses of NaCl stressed cowpea plants grown in nutrient solution supplemented with $CaCl_2$. Brazilian Journal of Plant Physiology, 15(2), 99-105. https://dx.doi.org/10.1590/S1677-04202003000200005

Solís, B.J.L., Muñoz, O.A., Escalante, E.J.A.S., y Zamarripa, C.A. (2016). Crecimiento de variedades y componentes del rendimiento de higuerilla (*Ricinus communis* L.) en Montecillo, Estado de México. Revista Mexicana de Ciencias Agrícolas, 7(2), 311-323.

Vasco, L.J.F. (2014). Análisis químico proximal y parámetros físicos de semillas de higuerilla (*Ricinus communis* L.) (tesina de maestría tecnológica). Colegio de Postgraduados – Campus SLP. Salinas de Hgo., SLP, México.

Velasco, L., Rojas-Barros, P., & Fernández-Martínez, J.M. (2005). Fatty acid and tocopherol accumulation in the seeds of a high oleic acid castor mutant. Ind. Crops Prod., 22, 201-206.

https://doi.org/10.32854/agrop.v14i05.1858

Parameters of Physical and Physiological Quality in Tomato Seeds Produced under High Temperature Condition during Different Periods of Development

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ABSTRACT

Objective: To evaluate the quality of the seeds of tomato fruits (*Solanum lycopersicum* Mill.) produced in high temperature (HT) during different phases of development.

Design/Methodology/Approach: Seeds of the Moneymaker variety were planted in a ventilated greenhouse (control treatment, CT) with maximum mean temperature (MMT) of 31.5 °C. A second greenhouse with artificial heating (MMT of 36.5 °C) was used for the HT treatments. When anthesis began from the fourth floral cluster, seven treatments were established: T1) fruits growing permanently in the CT; T2) fruits transferred to HT between five and 12 days after anthesis (daa); T3) fruits growing in HT from 12 to 24 daa; T4) 24-36 daa in HT; T5) 36-48 daa in HT; T6) 48-60 daa in HT; T7) from 60 daa to maturity in HT.

Results: The weight of one thousand seeds (SW) had a positive correlation with the length of seed (R=0.83*), indicating that the increase in SW was primarily determined by an increase in length. The vigor of the seed was measured by the germination after accelerated ageing (GAA); thus, germination and vigor are positively correlated with seed respiration during germination (0.62* and 0.81*, respectively).

Study Limitations/Implications: HT impacting on the second phase of seed development could decrease both the physical and physiological quality of tomato seeds.

Findings/Conclusions: The seeds produced by T7 had lower SW (2.99 g). T5 caused lower amount of seeds per fruit (120), germination (79.4%) and GAA (39.5%).

Keywords: Seed quality, growth, global warming.

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INTRODUCTION

The use of high quality seeds constitutes a basic element in agricultural production, which is fundamental in the initial phase of a crop: a high quality seed offers greater possibility for success in seedling establishment (Ayala-Garay *et al.*, 2016), in addition to having higher viability during storage (Pichardo-González *et al.*, 2014). The seed quality includes genetic, phytosanitary, physical (size, volume, etc.), and physiological (viability, germinative capacity, vigor) aspects (Bewley *et al.*, 2013). Seeds are complex structures that have three main components: the embryo that will develop into a vegetative seedling; the endosperm that provides nutrients for the development of the embryo during the first stages of the seedling; and the testa that covers the rest of the components to protect them and to control germination (Taylor, 2020). The start of seed development happens immediately after pollination, when the ovule is activated to begin cell division and histodifferentiation that will form the tissues of the embryo and endosperm. Simultaneously, water flows happen that expand the formed cells and carry compounds that allow the synthesis and storage of reserves. Seed maturation is reached with water loss (tissue disiccation) and the development of the processes that allow the seed to survive with low moisture contents (Taiz *et al.*, 2015). The quality factors are affected by the growth conditions of the parent plant during the phase of seed development.

Temperature is a defining factor on the growth and the different phenological phases of development of the cultivated plants (Hatfield and Prueger, 2015).

The increase in global temperature observed during the last century represents a challenge for agricultural production, since its effects have a substantial impact on the crops' yield (Xu *et al.*, 2017). The response to high temperature depends on the phenological stage of cultivation, and in addition, each species responds to a definite range of maximum and minimum temperatures that form the limits of observable growth (Hatfield and Prueger, 2015). Tomato is one of the most frequently cultivated vegetables in the world; it is used as model plant for the study of Solanaceae and species with berry type fruit (Xu *et al.*, 2017). It is considered a species that is sensitive to temperature increase, the optimal values for the growth and development of the crop range between 25 and 30 °C, while temperatures higher than these are detrimental (Taiz *et al.*, 2015). The increase in maximum diurnal and nocturnal temperatures, as well as the frequency and duration of the exposure to these, affect negatively the reproductive development and the physiology of tomato (Xu *et al.*, 2017).

There are few studies of the effect of high temperatures during the development of the crop on the quality parameters of tomato seeds (Xu *et al.*, 2017; Delgado-Vargas *et al.*, 2018). Thus, the effect of the affecting high temperature during different periods of seed development on physical (size and weight) and physiological (germination, vigor, respiration, and membrane permeability) variables was evaluated.

MATERIALS AND METHODS

The experiment was carried out in spring-summer in Texcoco, Mexico (19° 27′ 51″ N and 98° 54′ 15″ W, at 2250 m of altitude). The genotype used was *Solanum lycopersicum* var. Moneymaker (MM), of temperate origin, is considered a global reference in tomato studies (Biais *et al.*, 2014; Delgado-Vargas *et al.*, 2018).

One hundred seeds were sown in trays with peat moss number 3 (Sunshine, USA) as substrate, during 40 d. The seedlings were transplanted in black polyethylene bags of 10 L, with a mixture of 30:70 peat moss and tezontle substrate. The management of tomato plants was made according to conventional commercial practices.

Two tunnel-type greenhouses with zenithal ventilation and milky white polyethylene cover were used, one equipped with ventilators to generate the condition of control temperature (CT) and the other with a system of electric heaters to generate the condition of high temperature (HT) and thus obtain a difference in the diurnal temperature (7:00 to 19:00 h), maintaining a similar nocturnal temperature in both treatments. The maximum average temperature was 36.5 °C for HT and 31.5 °C for CT. The air temperature within the greenhouses was recorded every 10 min with Hobo® sensors (Onset Computer Corporation, USA).

The quality evaluation of the seeds was made in fruits from the fourth floral cluster. The plants remained in HT and once this cluster reached anthesis, the following seven treatments were established with n=10 plants: 1) plants growing permanently in HT; 2) plants transferred to HT between 5 and 12 daa from the 4th cluster and then returned to HT; 3) plants taken to HT at between 12 and 24 daa; 4) plants taken to HT at between 24 and 36 daa;

5) plants taken to HT at between 36 and 48 daa; 6) plants taken to HT at between 48 and 60 daa; and 7) plants taken to HT at 60 daa and until maturity. The treatments were established, considering an approximate duration of the fruits from the 4^{th} cluster until their maturity at 72 daa (Biais *et al*., 2014).

Fruit harvesting was carried out in maturity degree 6 (more than 90% of the surface of the fruit is red) (Wan *et al*., 2018). Seed extraction was made manually from n=20 fruits chosen randomly, through fermentation of the mucilage, then dried at room temperature and forming a single seed lot that was kept at room temperature for 60 d.

Variables

The number of seeds per fruit (NSF) was counted at the time of dissecting the fruit. After the seed storage period, laboratory trials were carried out; the moisture content of the seed was determined in a sample of 0.5 g of seed dried in a conventional Thelco (USA) stove at 103 °C during 17±1 h, which together with the initial weight of the sample was used to calculate the moisture content of the seed lot (expressed in %).

The weight of one thousand seeds (SW, in g) was obtained with the standard procedure by ISTA (2012); four repetitions were used made up of eight samples of 100 seeds, which were weighed in an Ohaus scale (Pine Brook, China), with accuracy of 0.001 g, multiplying the average by 10. The seed length (SL) and width (SW) were measured in four repetitions of 100 seeds, through the processing of images with the Image J® software; for this purpose, the seeds were scanned in a multifunctional HP2200 printer (Hewlett Packard, USA) capturing images of 1200 dpi, and both variables were expressed in mm.

For the germination test, four repetitions of 100 seeds were used, which were sown in Petri dishes with moistened filter paper and placed in a SD8900 germinator (Seedburo Inc., USA) at 25±1 °C for 14 d (ISTA, 2012). The percentage of germination (G, %) was calculated taking into account the number of normal, healthy seedlings and without malformations.

The seed vigor was evaluated with an accelerated ageing test; four repetitions of 100 seeds were used, which were subjected to 41 °C and relative humidity of 100% during 72 h, and after this time the seeds were evaluated in a germination test (GAA).

Electric conductivity (EC, $\mu S\ cm^{-1}\ g^{-1}$) of the imbibition solution was determined using four repetitions of n=20 seeds that were previously weighed and placed in 20 mL of deionized water at 25 °C for 24 h; after this time, the EC of the solution was measured with a Model 72729 conductometer (Oakton, Singapur). The respiratory rate of the seed during germination was also evaluated (Resp, nmol $CO_2\ g^{-1}\ s^{-1}$), which was measured in four repetitions of 20 seeds with 5 d of imbibition with a CI-301PS photosynthesis meter (CID Inc., Canada).

Experimental analysis

A completely randomized experimental design was used. The means comparison test was carried out with Tukey's method (P≤0.05). The statistical analyses were made with the Infostat statistical program version 2016e (Universidad de Córdova, Argentina). To normalize the data of the variables that were recorded in percentage, they were transformed with the following formula: Arcsine $\sqrt{x}/100$.

RESULTS AND DISCUSSION

The moisture content of the seeds from the treatments evaluated had an average of 7.6±0.1%, value that does not interfere with the rest of the physical, physiological and biochemical variables because in dry seeds, as is the case, the biological processes are slower than in moist seeds (Ayala-Villegas *et al*., 2014; Taylor, 2020). After the harvest, the moisture content of the seed decreases until reaching a dynamic equilibrium with the environment surrounding it (Rodríguez-Burgos *et al*., 2011).

Physical quality of seeds

The weight of one thousand seeds (SW), the seed length (SL) and the number of seeds per fruit (NSF) presented significant differences (P≤0.05) caused by the treatments studied. Only in the variable seed weight (SW) the differences caused by the treatments were not statistically significant (Table 1).

The seeds produced by treatment seven were showing less weight (2.99 g) compared to the rest of the treatments (Figure 1A), only treatment four was statistically similar; reductions of 6.3 and 4.1% were found, respectively, compared to the highest value (Treatment 1, 3.19 g). Treatments one to six produced seeds with statistically similar weight, the average of SW of these six treatments was 3.14 g. The SW values obtained in this study are similar to those reported by Delgado-Vagas *et al*. (2018) for var. Moneymaker. According to Hampton *et al*.

Table 1. Mean squares and statistical significance in the analysis of variance of the physical quality variables of the Moneymaker seeds produced under seven high temperature conditions

SV	1000-seeds weight (g)	Seed length (mm)	Seed width (mm)	Number of seeds
Treatment	0.02 *	0.22 *	0.14 ns	1246.21 *
Error	0.0026	0.0900	0.0800	0.0024
CV	1.65	10.66	8.28	21.81

SV=source of variation; CV=Coefficient of variation; **=highly significant (P≤0.01); *=Significant (P≤0.05); ns=Not significant.

(2013), the increase in temperature can reduce the mass of the seed due to acceleration in the growth rate and reduction in the time of seed filling, and this was probably the reason why the seed did not reach higher weight in treatment seven, whose fruits were subjected to high temperature between 60 daa and fruit maturity, that is, in the last period of their development. The SW values had a positive correlation (R) with those of SL of 0.83* (Figure 1A and 1C), indicating that the increase in SW was mainly determined by a greater growth in seed length.

Treatment five caused the lowest number of seeds per fruit (120) and was statistically similar to treatments six and seven (Figure 1B). The NSF average of treatments one to four, whose values were statistically similar, was 169 seeds fruit^{-1}. These values were found within the segment of values found by Delgado-Vagas *et al*. (2018).

Physiological quality of seeds

When it comes to physiological quality, it was found that germination (G) and germination after subjecting the seeds to accelerated ageing (GAA), variable that is considered an expression of seed vigor (Ayala-Garay *et al*., 2018), showed highly significant differences (P≤0.01) as an effect of the treatments studied. In the variable electric conductivity of the imbibition solution (EC) and respiration of the seed during germination (Resp), only significant differences were found (P≤0.05; Table 2).

The values with maximum germination were observed in treatments 1, 2, 3, 4 and 7. Treatment five presented the lowest values of germination and vigor (expressed by the variable GAA) of seeds, with 79.4 and 39.5%, respectively (Figures 2A and 2B). In both variables the values increased immediately after, in treatments 6 and 7.

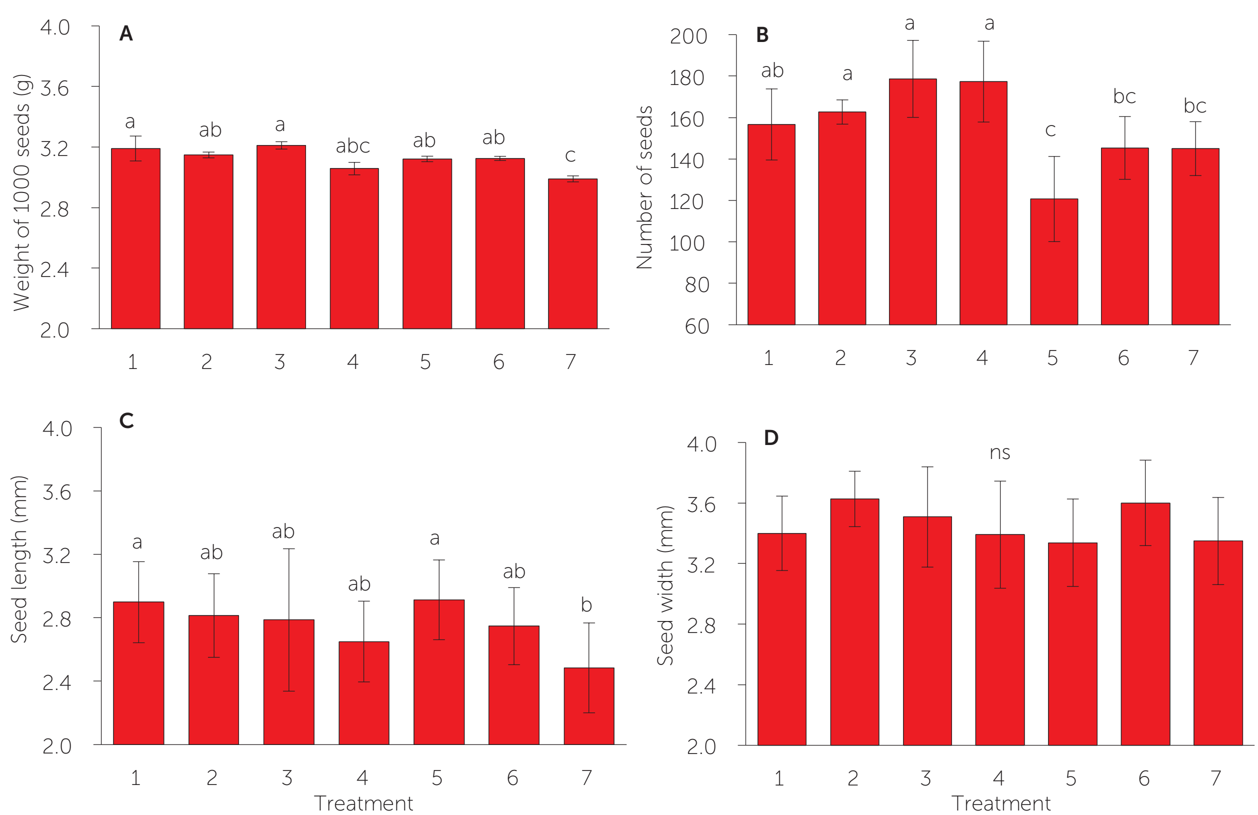

Figure 1. (A) Weight of 1000 seeds (B) Number of seeds per fruit, (C) Seed length (D) Seed width of the seeds of Moneymaker tomato variety produced under seven high temperature conditions. The bars indicate the standard error (n=4). Small letters and "ns" indicate statistical significance between means (Tukey, P≤0.05).

Table 2. Mean squares and statistical significance in the analysis of variance of the physiological quality variables of the Moneymaker seeds produced under seven high temperature conditions.

SV	Germination (%)	Germination after AA (%)	Electric Conductivity (μS cm^{-1} g^{-1})	Respiration (nmol CO_2 $g^{-1}s^{-1}$)
Treatment	0.06 **	0.16 **	52.62 *	38.13 *
Error	0.0100	0.0100	1.300	0.117
CV	5.76	13.68	14.30	30.65

SV=source of variation; CV=Coefficient of variation; AA=Accelerated ageing; **=Highly significant (P≤0.01); *=Significant (P≤0.05); ns=Not significant.

Accelerated ageing decreased seed germination of all the treatments, going from 94% in seeds without ageing to 67% average in aged seeds. Since vigor can be positively correlated with seed deterioration, the capacity of a seed lot to survive artificial ageing is correlated with its vigor and potential of longevity in storage (Bewley *et al*., 2013).

The EC test is used as an indicator of the physiological quality in seeds (ISTA, 2012). When measuring the electric conductivity of the imbibition solution, the solutes liberated by the seeds are measured, which is inversely proportional to their germinability and vigor, since it is considered that a higher EC indicates that the organization or integrity of the membranes is deficient. In this experiment, the variable EC did not represent a useful element for the analysis, since when the highest values of germination and vigor (treatment one, for example) and when the lowest (treatment five) were found, the values of EC were statistically lower than the group, which is inconsistent with countless authors (Martínez-Muñoz *et al*., 2019).

Another variable related to seed vigor is respiration, which is controlled by the quantity of respirable substrates such as carbohydrates (Bewley *et al*., 2013). In this study, respiration of the seed on the fifth day of imbibition (Resp) had a similar behavior in G and

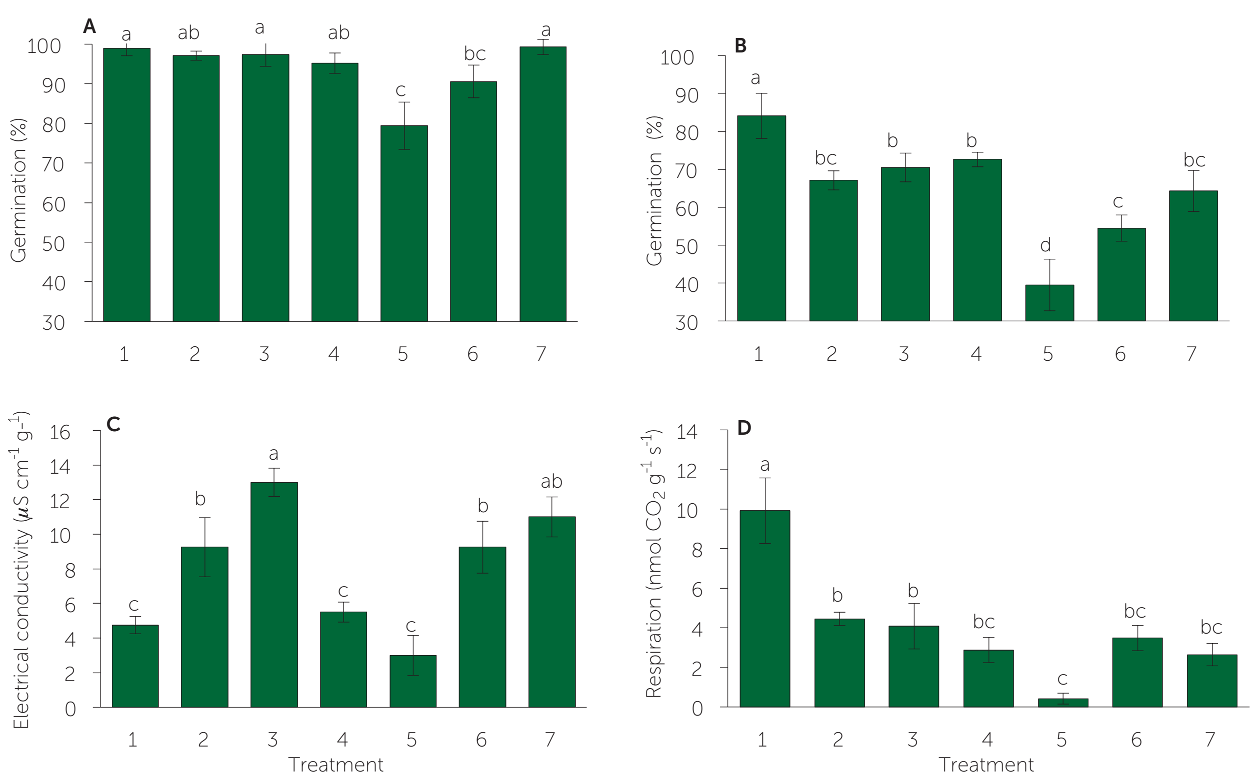

Figure 2. (A) Germination, (B) Germination afer accelerated ageing, (C) Electrical conductivity of the imbibition solution, and (D) Seed respiration rate at the fifth day after started germination in the seeds of Moneymaker tomato variety produced under seven high temperature conditions. The bars indicate the standard error (n=4). Small letters indicate statistical significance between means (Tukey, P≤0.05).

GAA, since the lowest value was observed in treatment five. Seed respiration provides energy required for the germination (Pérez-Camacho *et al*., 2008) and its intensity depends on the functionality of mitochondria (Bewley *et al*., 2013). Therefore, vigorous seeds require higher energetic contribution than non-vigorous ones (Pérez-Camacho *et al*., 2008). In this study, the value of the correlation between G and Resp was 0.62* and between GEA and Resp it was 0.81* (Figure 2). The magnitude of the values of Resp recorded in this study is similar to what was observed by Delgado-Vargas *et al*. (2018) in tomato seeds.

CONCLUSIONS

The maximum average temperature of 36.5 °C applied since 60 daa and until fruit harvest resulted in seeds with lower weight and less length. When the tomato fruits were placed at between 36 and 48 daa at this temperature, a lower number of seeds per fruit, germination, respiration value of the seed during germination, and vigor were found. Thus, the high temperature affects the second phase of fruit development provoking lower physical and physiological quality of the seed.

REFERENCES

Ayala-Garay, O. J., Garfias-Sánchez, D. y Delgado-Vargas, V. A. (2016). Producción de hortalizas y sus semillas en el huerto de traspatio. Texcoco, México: Colegio de Postgraduados.

Ayala-Garay, O. J., Pinzón-López, L. L., Latournerie-Moreno, L., Ayala-Garay, A. V. y Tovar-Carvajal, S. (2018). Adaptaciones metodológicas para evaluar la calidad fisiológica en semillas de chile habanero (*Capsicum chinense* Jacq.). Agroproductividad, 11(9), 9-14. doi: 10.32854/agrop.v11i9.1208

Ayala-Villegas, M. J., Ayala-Garay, O. J., Aguilar-Rincón, V. H. y Corona-Torres, T. (2014). Evolución de la calidad de semilla de *Capsicum annuum* L. durante su desarrollo en el fruto. Revista Fitotecnia Mexicana, 37(3), 79–87. Recuperado de http://www.scielo.org.mx/pdf/agritm/v32n3/v32n3a7.pdf

Bewley, J. D., Bradford, K. J., Hilhorst, W. H. M. y Nonogaki, H. (2013). Seeds. Physiology of development, germination and dormancy. New York, USA: Springer.

Biais, B., Bénard, C., Beauvoit, B., Colombié, S., Prodhomme, D., Ménard,… Gibon, Y. (2014). Remarkable reproducibility of enzyme activity profiles in tomato fruits grown under contrasting environments provides a roadmap for studies of fruit metabolism. Plant Physiology, 164(3), 1204-1221. doi: 10.1104/pp.113.231241

Delgado-Vargas V. A., Magdaleno-Villar J. J., Ayala-Garay O. J. y Garfias-Sánchez D. (2018). Seed quality of three native tomato varieties and a commercial one produced under high temperatures. Revista Chapingo Serie Horticultura, 24(3), 215-227. doi: 10.5154/r.rchsh.2018.04.009

FAO (Food and Agriculture Organization of the United Nations). 2015. Coping with climate change – the roles of genetic resources for food and agriculture. Rome, Italy: FAO editions.

Hampton J. G., Boelt B., Rolston M. P. y Chastain T. G. (2013). Effect of elevate CO_2 and temperature on seed quality. Journal of Agriculture Science, 151(2), 154-162. doi: 10.1017/S0021859612000263

Hatfield, J. L. y Prueger J. H. (2015) Temperature extremes: Effect on plant growth and development. Weather and Climate Extremes, 10(Part A), 4–10. doi: 10.1016/j.wace.2015.08.001

ISTA (International Seed Testing Association). (2012). International Rules for Seed Testing. Rules 2012. Bassersdorf, Switzerland: ISTA Editions. Recuperado de: https://www.seedtest.org/en/home.html

Martínez-Muñoz M., Ayala-Garay O. J., Aguilar-Rincón V. H., Conde-Martínez V. y Corona-Torres T. (2019). Seed quality and LEA-protein expression in relation to fruit maturation and post-harvest storage of two chilies types. The Horticulture Journal 88(2), 245-252. doi: 10.2503/hortj.UTD-04.

Pérez-Camacho I., Ayala-Garay O. J., González-Hernández V. A., Peña-Lomelí A., Cárdenas-Soriano E., Carrillo-Salazar A. y García-de los Santos G. (2008). Morphological and physiological markers of seed deterioration in husk tomato. Agrociencia, 42(8), 891-901. Recuperado de https://agrociencia-colpos.mx/index.php/agrociencia/article/view/685/685

Pichardo-Gonzalez, J. M., Ayala-Garay, O. J., González-Hernández, V. A. y Flores-Ortiz, C. M. (2014) Fatty acids and physiological quality of tomatillo (*Physalis philadelphica* Lam.) seed during natural ageing. Chilean Journal of Agricultural Research, 74(4), 391-396. doi: 10.4067/S0718-58392014000400003

Rodríguez-Burgos, A., Ayala-Garay, O. J., Hernández-Livera, A., Leal-León, V. M. y Cortez-Mondaca, E. (2011). Desarrollo de fruto y semilla de cinco variedades de tomate de cáscara en Sinaloa. Revista Mexicana de Ciencias Agrícolas, 2(5), 673-687. Recuperado de: http://www.scielo.org.mx/pdf/remexca/v2n5/v2n5a4.pdf

Taiz, L., Zeiger, E., Møller, I. M. y Murphy, A. (2015). Plant physiology and development. Sunderland, Massachusetts: Sinauer Associates, Inc., Publishers.

Taylor A. G. (2020). Seed storage, germination, quality and enhancement. En: H.C. Wien y H. Stützel (Eds.). The physiology of vegetables crops (pp. 1-30). Oxfordshire, United Kingdom: CAB International.

Wan, P., Toudeshki, A., Tan, H., y Ehsani, R. (2018). A methodology for fresh tomato maturity detection using computer vision. Computers and Electronics in Agriculture, 146(C), 43-50. doi: 10.1016/j.compag.2018.01.011

Xu, J., Wolters-Arts, M., Mariani, C., Huber, H. y Rieu, I. (2017). Heat stress affects vegetative and reproductive performance and trait correlations in tomato (*Solanum lycopersicum*). Euphytica, 213, 156. doi: 10.1007/s10681-017-1949-6

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Traceability in the Global Value Chain of Blueberry between Mexico and China

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ABSTRACT

Objective: To analyze the traceability system required by the Phytosanitary Protocol signed between Mexico and China for the export of fresh blueberries.

Design/Methodology/Approach: The case study approach is used to analyze the Global Value Chain of Blueberry between Mexico and China (GVCBMC). The information is obtained through semi-structured interviews and bibliographical analysis.

Results: The traceability system of blueberry is influenced by the differentiation of attributes of innocuousness and plant health that comply with the regulations established by the Chinese government to allow the influx of fresh blueberry to their market. The traceability system provides and recovers information through the use of codes in labels.

Study Limitations/Implications: The traceability system of the Global Value Chain of a single product destined to a specific market was analyzed, so it cannot be generalized.

Findings/Conclusions: The companies that are part of the Global Value Chain of Blueberry between Mexico and China use the traceability system along with other tools that allow the management of quality, innocuousness, plant health and logistics, to provide information about the product, to make decisions about payments and to comply with regulations.

Keywords: Traceability, blueberry, *Vaccinium*, Global Value Chain.

INTRODUCTION

Governments influence the Global Value Chains (GVC) by establishing tariff and administrative barriers (Ponte & Sturgeon, 2014). The nature and type of barrier will depend on the demands imposed by each country to each product. In China, the main barrier for the entry of fresh blueberry to its market is the signature and compliance with a phytosanitary protocol (Produce Marketing Association, 2016).

In November 2016, the protocol of plant health requirements for the export of fresh blueberry fruits from Mexico to China was signed, which was subscribed between China's General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and Mexico's Ministry of Agriculture, Livestock Production, Rural Development, Fishery and Food (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, SAGARPA). The protocol establishes the requirements that must be fulfilled to export fresh Mexican blueberries to the Chinese market (SAGARPA, 2016).

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Among the requirements, the following stand out: mandatory registry of plots and refrigerators, control registry of good agricultural practices and integral management of pests, inspections for quarantine pest control, supervision of the use of new and clean packaging, use of clean containers in transport, use of a traceability label, inspections and analysis of samples before the export to issue the phytosanitary certificate, and inspection of the fruit at the moment of arrival to authorized airports (SAGARPA, 2016). The satisfaction of the requirements represents a necessary condition for the company to gain access to the market (Dabbe *et al.*, 2014).

In June 2017, the GVCBMC was established with the first aerial shipment of fresh blueberry from Guadalajara to Shanghai, which consisted of two pallets with 420 boxes, containing a volume of 630 kg of 'Sophia' blueberry developed by the Fall Creek Company exclusively for independent producers of the Berries Paradise trader (Portal Frutícola, 2017).

In 2018, 30 plots were authorized with a total of 779 ha belonging to various producers located in 13 municipalities of the states of Colima, Jalisco, Michoacán and Sinaloa (SENASICA, 2018b). That same year, 12 refrigerators located in the same states belonging to seven trader companies were authorized for the export of fresh blueberry to China: Berries Paradise (four), Driscoll's (three), Hortifrut (one), Exportadora Internacional de Frutas (one), Sun Bell (one), FH Internacional de México (one) and Fuerte Fe (one) (SENASICA, 2018a).

These actors and the activities that they perform determine the complexity and characteristics of the traceability system (Behnke & Jansen, 2019), so their identification and description are required to understand it (Regattieri *et al.*, 2007). The objective of this study is to analyze the traceability system used by the companies that are members of the GVCBMC, and to identify the activities that they perform and the actors that participate in these activities to comply with the plant health protocol signed between Mexico and China for the export of fresh blueberries.

In this regard, the implementation of a traceability system is a challenge, since the different actors in the chain require collaboration between them to implement the activities related to the management of the quality, innocuousness, plant health and logistics of the product. Thus, a greater collaboration impacts with more certainty on the quality of the product (Charlebois & Haratifar 2015), but at the same time, requires a greater commitment between the different actors of the chain (Wohlrab *et al.*, 2016). Facing such a dilemma, this study establishes in a detailed manner the activities implemented by the GVCBMC that allows for a traceability system to comply with the tracking and origin of the product, differentiation of the product, and easing the flow of information between parts.

MATERIALS AND METHODS

Qualitative research of a case study with a descriptive approach was carried out (Yin, 1998). To gather information, the guidelines for the export of fresh blueberry fruits from Mexico to China were analyzed, and semi-structure interviews were performed in the blueberry industry to increase the validity and reliability of the study.

Based on the general questions proposed by Charlebois & Haratifar (2015): who (product/economic agent), what (product information), when (time), where (location), how (production practices), and why (cause/reasons) are related with the traceability of fresh blueberry exported to China.

RESULTS AND DISCUSSION

Traceability System

The traceability system can be described as the documented identification of the operations of production, commercialization and distribution that lead blueberry from the Mexican farmland to the table of Chinese consumers (Bertolini *et al.*, 2006). The traceability system used by the GVCBMC (Figure 1) shows the information related to the compliance of the phytosanitary protocol that defines which data should be gathered and recorded from the production to the distribution and how they are associated to standards of innocuousness and plant health, becoming established as a tool to comply with the legislation associated with the requirements of a country (Aung and Chang, 2014).

Production

The traceability system begins with the connection between the producer and the trader. Once the production contract is signed, the producers receive exhaustive training from the trader in form of technical advice (on the sowing, fertilization, irrigation, pruning,

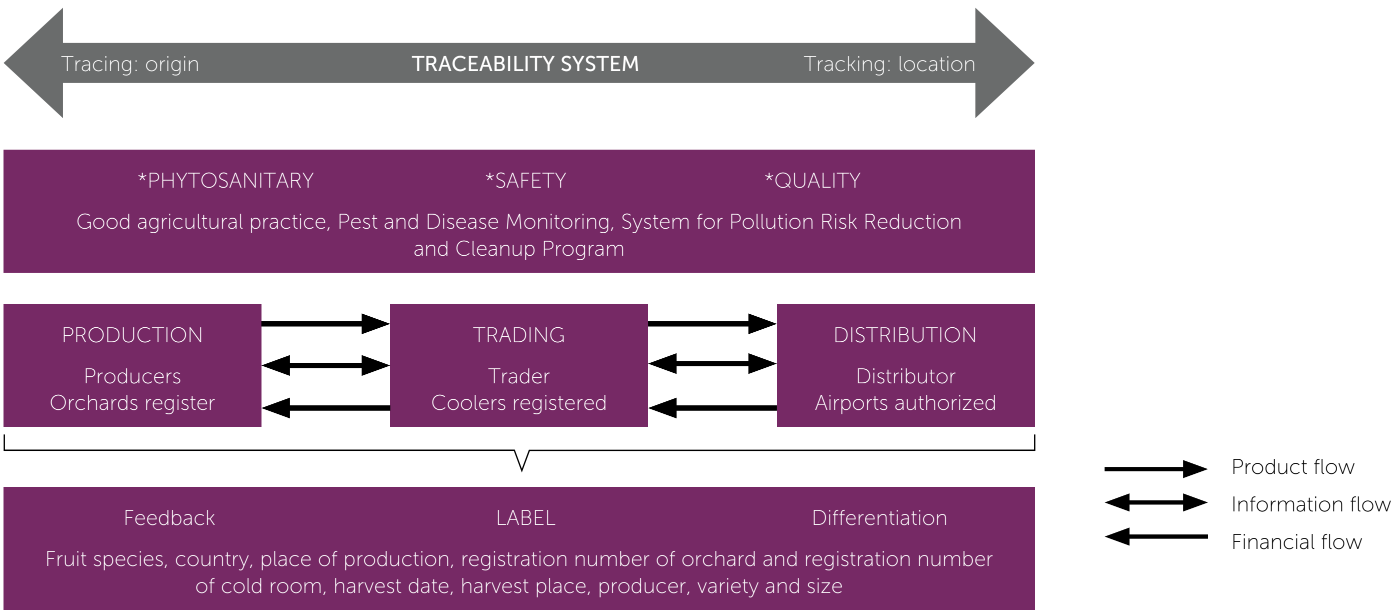

Figure 1. GVCBMC Traceability System. Own elaboration.

harvest, selection, packaging and delivery) and indications about the fruit quality and requirements of innocuousness and plant health that they must fulfill.

The producers as the ones directly responsible for the crop management, they are obligated to have and follow an integral pest and disease management program, and to maintain a monitoring record of pests of interest to China and present in Mexico, such as: cherry moth (*Cydia packardi*), Putnam scale (*Diaspidiotus ancylus*), apple mussel scale (*Lepidiotus ulmi*), tarnished plant bug (*Lygus hesoerus*); and of the mechanical (collection and elimination of fruit in trough), chemical (registry of pesticide application), biological (use of parasitoids and predators), and cultural (pruning) control that they carry out in blueberry cultivation.

Among the activities that are recorded by the technical staff authorized by the National Service for Agrifood Health, Innocuousness and Quality (Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria, SENASICA), there are the following: good agricultural practices (GAP), traps, pest monitoring and sampling, application of pesticides authorized by the Federal Commission for the Protection against Sanitary Risks (Comisión Federal para la Protección contra Riesgos Sanitarios, COFEPRIS) and allowed by the General Administration of China's Supervision of Quality, Inspection and Quarantine (AQSIQ). In addition, the producers are subscribed to the program of contamination risk reduction system (CRRS) that allows them to detect and prevent risks of contamination and to preserve the innocuousness of the blueberry fruit.

The General Direction of Plant Health (Dirección General de Sanidad Vegetal, DGSV) is in charge of performing the verification of these activities, giving a registry number to the plots of producers who comply with the requirements and which are authorized by the Ministry of Agriculture and Rural Development (Secretaría de Agricultura y Desarrollo Rural, SADER) and the AQSIQ for the export of blueberries to China.

Bottling and packaging of blueberry is carried out in the authorized plots in areas that have exterior isolation (anti-aphid mesh, double door or Hawaiian shutters). Blueberries are bottled in "clamshells" of 125 g that are new and clean, and packaged in new and clean carton boxes (12 clamshells per box weighing 1.5 kg), fruit that is free from plant residues, soil and damaged fruits.

Two labels are placed on the fruit sent to the trader. The traceability label from the trader is placed on the clamshells, which are the smallest units that the final consumer purchases and which contain blueberries from a single producer. In general this label contains unique data for each transaction: date and place of harvest, name of producer, name of variety and caliber. The codes help in the accurate and quick identification of the information expressed on the label (Olsen & Borit, 2013).

The second label, of traceability established by the phytosanitary protocol, is placed on the box specifying the fruit species (blueberry), country of origin (Mexico), and place of production (municipality and state), registry number of the plot (PRE03/--state/---municipality/----name of the plot) and registry number of the refrigerator (CFA01/--state/---municipality/----facilities). The data from this label does not change throughout the season since blueberry can only be sent from authorized producers and traders. The information of the traceability label of the protocol is backed by documentation such as: logbooks, notebooks and registries that must be made available to the appropriate authorities every time they are requested.

Finally, the carton boxes (which provide additional information: quantity, weight and size) are sent from the plot to the refrigerator in clean and closed transport, avoiding mixing the product with another one destined to a different market to prevent any type of contamination.

Commercialization

The condition of perishability of blueberry (depending on the variety, 25 days in 'Sophia') forces the traders to have conservation means. The traders inscribe one or several refrigerators, depending on their needs. Each refrigerator is equipped to carry fruit at a temperature of 0 °C to 2 °C with a relative humidity of 90% to 95%. In addition, a cleanliness program and a CRRS are applied in each of them, to ensure the safety.

In each refrigerator an exclusive space is allotted for the management and storage of blueberries that have China as destination, which is separate from the space assigned to shipping to other markets. This space has an exclusive inspection table with material required to carry out the flotation test, which consists in taking a sample of the fruit, macerating it, placing it in a plastic bag with water and sugar, and observing if there are floating larvae.

Fruit species:
Country:
Place of Production:
Registration number of orchard:
Registration number of cold room:

"输往中华人民共和国"
(Exporting to the People's Republic of China)

Figure 2. GVCBMC Traceability Label. Source: (SAGARPA, 2016).

Once compliance of the activities established by the phytosanitary protocol is shown, a registry number is given to those refrigerators authorized for the export and logbooks are kept with information about verification visits, audits or monitoring from SENASICA or AQSIQ, which can be performed any moment.

When it is authorized and operating, the person responsible for each refrigerator records the date of reception, the registry number of the plot, the product, and the number of boxes received. The traceability label of the product (Figure 2) placed on the packaging eases the management of operations by the trader since it allows the identification of the product from among all the blueberry packages that it receives with different attributes.

With this label, blueberry destined for China is separated, tracked, and placed in the authorized place. The traceability label also makes payment to the producer simpler, since price fixing in in function of the added value in terms of quality, innocuousness and plant health (Tang *et al*., 2015).

Every shipping is inspected by personnel authorized by SENASICA (third phytosanitary specialist or authorized phytosanitary officer). The staff performs a phytosanitary inspection of 2% of the total boxes that make up the shipping through destructive and non-destructive tests to detect pests. If the sample is free of pests, and complies with the Maximum Residual Limit of Pesticides allowed by China, the shipping is approved, and the International Phytosanitary Certificate is issued. Contrary case, the corrective actions are indicated and the plot is excluded from exports until they are performed and it is verified that they are in place.

Authorized blueberry is palletized and pre-cooled at a temperature of 0 °C, and then each pallet is covered with a mesh and the traceability label of the phytosanitary protocol is placed, with the legend indicating that the product will be exported to China. The characteristics of the pallet in terms of dimensions and weight allow satisfying the logistical needs that ease the aerial transport and mobility of the product. The pallets are transported to the Guadalajara airport in closed, refrigerated and clean vehicles, equipped with devices that measure the variations in temperature and light during transport.

Distribution

The second link is formed between the trader and the distributor, through supply programs established each season. The trader tends to send blueberry to the distributor from different authorized producers to reach the volume requested for each shipping. The traceability label helps in the commercial part, since if the distributor likes or dislikes the blueberry from a producer in particular, it can be identified through the codes expressed on the label (Golan *et al*., 2004).

In addition, the traceability label allows the trader to receive information from the distributor on the condition of the blueberry from each producer in its attributes of quality, innocuousness and plant health (Karlsen *et al*., 2013). In this stage, traceability helps the payment and continuous improvement systems.

CONCLUSIONS

The companies that make up the Global Value Chain of Blueberry between Mexico and China use the traceability system as a tool that supports the management of quality, innocuousness, plant health and logistics. The traceability system allows tracking the origin and monitoring the fresh blueberry produced in Mexico, easing its physical flow; the differentiation of the product and market, easing the flow of capital when making payments to the producers; and the feedback from companies, easing the flow of information between actors. In addition, the traceability system gathers all the relevant information of the activities performed and not performed as indicated in the phytosanitary protocol, and presents them through a traceability label that reflects the conditions of origin, manipulation and storage of blueberry; and which complies with the information and the guidelines requested by the destination market.

REFERENCES

Aung, M. M., & Chang, Y. S. (2014) Traceability in food supply chain: Safety and quality perspectives. Food control, 39: 172-184. doi: 10.1016/j.foodcont.2013.11.007

Behnke, K., & Jansen, M. F. W. H. A. (2019). Boundary conditions for traceability in food supply chains using blockchain technology. International Journal of Information Management, 52, 101969. doi: 10.1016/j.ijinfomgt.2019.05.025

Bertolini, M., Bevilacqua, M., & Massini, R. (2006) FMECA approach to product traceability in food industry. Food control, 17(2): 137-145. doi: 10.1016/j.foodcont.2004.09.013

Charlebois, S., & Haratifar, S. (2015). The perceived value of dairy product traceability in modern society: An exploratory study. Journal of dairy science, 98(5): 3514-3525. doi: 10.3168/jds.2014-9247

Dabbene, F., Gay, P., & Tortia, C. (2014). Traceability issues in food supply chain management: A review. Biosystems engineering, 120: 65-80. doi: 10.1016/j.biosystemseng.2013.09.006

Golan, E. H., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. E., & Price, G. K. (2004). Traceability in the US Food Supply: Economic Theory and Industry Studies (Agricultural Economic Report Number 830). United States Department of Agriculture, Economic Research Service. Recuperado de: https://ageconsearch.umn.edu/record/33939

Karlsen, K. M., Dreyer, B., Olsen, P., & Elvevoll, E. O. (2013). Literature review: Does a common theoretical framework to implement food traceability exist? Food Control, 32(2): 409-417. doi: 10.1016/j.foodcont.2012.12.011

Olsen, P., & Borit, M. (2013). How to define traceability. Trends in food science & technology, 29(2): 142-150. doi: 10.1016/j.tifs.2012.10.003

Ponte, S., & Sturgeon, T. (2014). Explaining governance in global value chains: A modular theory-building effort. Review of International Political Economy, 21(1): 195-223. doi: 10.1080/09692290.2013.809596

Portal Frutícola. (2017, Junio 15). Primeros arándanos mexicanos parten a China de la mano de Berries Paradise. Recuperado de: https://www.portalfruticola.com/noticias/2017/06/15/primeros-arandanos-mexicanos-parten-china-la-mano-berries-paradise/

PMA (Produce Marketing Association) (2016). Exporting fresh fruit and vegetables to China: A market overview and guide for foreign suppliers, PMA. pp. 9-14.

Regattieri, A., Gamberi, M., & Manzini, R. (2007). Traceability of food products: general framework and experimental evidence. Journal of food engineering, 81(2): 347-356. doi: 10.1016/j.jfoodeng.2006.10.032

SENASICA (Servicio Nacional de Sanidad, Inocuidad y Calidad Alimentaria) (2018a, Marzo 20). Listado de frigoríficos inscritos para exportar a China. Gobierno de México, SENASICA, Huertos registrados para exportación a China. https://www.gob.mx/cms/uploads/attachment/file/310847/Listado_de_Frigor_ficos_de_berries_para_exportaci_n_a_China_2018.pdf

SENASICA (Servicio Nacional de Sanidad, Inocuidad y Calidad Alimentaria) (2018b, Marzo 20). Listado de predios inscritos para exportar a China. Gobierno de México, SENASICA, Huertos registrados para exportación a China. https://www.gob.mx/cms/uploads/attachment/file/310849/Lista_de_Predios_inscritos__para_exportar_a_China_2018.pdf

SAGARPA (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación) (2016, Noviembre 25). Protocolos para la exportación de arándanos a China. Gobierno de México, SENASICA, Protocolos para la exportación. https://www.gob.mx/senasica/documentos/protocolos-para-exportacion

Tang, Q., Li, J., Sun, M., Lv, J., Gai, R., Mei, L., & Xu, L. (2015). Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation. Bioscience trends, 9(1): 7-15. doi: 10.5582/bst.2015.01004

Wohlrab, R. Steghöfer, J, Knauss, E., Maro, S., & Anjorin, A. (2016). Collaborative Traceability Management: Challenges and Opportunities. IEEE 24th International Requirements Engineering Conference (RE), Beijing, (pp. 216-225). doi: 10.1109/RE.2016.17.

Yin, R. K. (1998). The abridged version of case study research: Design and method. *In*: L. Bickman & D. J. Rog (Eds.), Handbook of applied social research methods, (pp. 229–259). USA: Sage Publications.

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Fusarium oxysporum f. sp. *niveum*: Causal Agent of Vascular Wilt of Watermelon

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ABSTRACT

Objective: To describe *Fusarium oxysporum* f. sp. *niveum* (*Fon*) as the causal agent of vascular wilt in the watermelon crop (*Citrullus lanatus* (Thunb.) Matsum and Nakai).

Design/Methodology/Approach: A review of scientific literature (scientific books, notes and articles) was carried out about *Fon* as the causal agent of vascular wilt in the watermelon crop; biology, symptoms, disease cycle, isolation and management alternatives.

Results: *Fusarium* wilt in watermelon is the main fungal disease of this crop worldwide. Necrosis of the vascular tissue and wilt of the plant are the most characteristic symptoms of the disease. There are four races of this fungus (*Fon* race 0, 1, 2 and 3); the commercial varieties of watermelons have different degrees of resistance to these races. Practices such as the correct diagnosis, use of grafts, solarization, fungicides, biological products and genetic resistance can significantly reduce the impact of the disease on the production.

Findings/Conclusions: In Mexico, knowledge about vascular wilt of watermelon is scarce despite this disease being one of the factors that limits commercial production. The greatest knowledge about the symptoms, the fungus's biology, presence and distribution of races, diagnosis and alternatives of *Fon* management, will allow integrating appropriate management practices that favor the commercial production of the crop.

Keywords: *Citrullus lanatus*, *Fusarium oxysporum* f. sp. *niveum*, vascular wilt.

INTRODUCTION

Cultivating watermelon (*Citrulllus lanatus* (Thunb.) Matsum. & Nakai) at the national level has great importance because of the amount of labor that it requires annually. Mexico is one of the eleven top watermelon producing countries in the world, with a production of 1,345,705 t, and an approximate surface of 40,000 ha (SIAP, 2020). The diseases that affect the crop constitute a limitation for its production in many parts of the world, particularly when cultivars with resistance are not used. Among these diseases, vascular wilt caused by *Fusarium oxysporum* f. sp. *niveum* (*Fon*) stands out due to its importance, since it

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is the main fungal disease that affects the watermelon crop in the whole world, with the ability to cause losses of up to 100% when cultivars with fungus resistance are not used (Dau *et al*., 2009). It was observed for the first time at the beginning of the decade of the 1890s, in southern United States, where it caused severe losses to farmers (Martyn, 2014). Presently this disease has been described in every continent of the world where watermelon is cultivated, except in the Antarctica (Egel & Martyn, 2007). In Mexico, the scientific information about *Fon* is scarce; it has been generated in its majority in other countries, particularly the United States. Therefore, and taking into consideration that vascular wilt from *Fusarium* in watermelon cultivation continues to be a limiting factor for commercial production, there is the need to generate updated, clear and accurate information that allows a greater comprehension about this disease.

MATERIALS AND METHODS

A review of scientific literature (scientific books, notes and articles) was carried out, about the importance of *Fon* as the causal agent of vascular wilt in the watermelon crop: biology, symptoms, disease cycle, isolation and control.

RESULTS AND DISCUSSION

Biology of *Fusarium oxysporum* f. sp. *niveum*

Fusarium oxysporum is a cosmopolitan pathogen capable of causing vascular necrosis, withering and death of plants in more than 100 plant species of agronomic importance (Rana *et al*., 2017). *Fon* does not have a known sexual phase, and it produces three types of asexual spores: microconidia, macroconidia and chlamydospores (Figure 1A, 1B, 1C), in addition to short phialides (Figure 1D). Microconidia play a role of low importance in the initial infections in the field due to their short-lived nature, while macroconidia have a more relevant role in the survival of the fungus, since they have the capacity of forming chlamydospores (resistance structures) (Egel & Martyn, 2007), which can survive in the soil for many years, making cultivation in fields infested with the fungus difficult (Kang *et al*., 2014).

The range of hosts of *Fusarium oxysporum* is very broad at the species level, since there are more than 120 special forms that affect plants from different botanical families (Michielse & Rep, 2009). In turn, these special forms are subdivided into races, which are described in function of their virulence or pathogenicity to specific varieties of the same plant species which vary in resistance to the

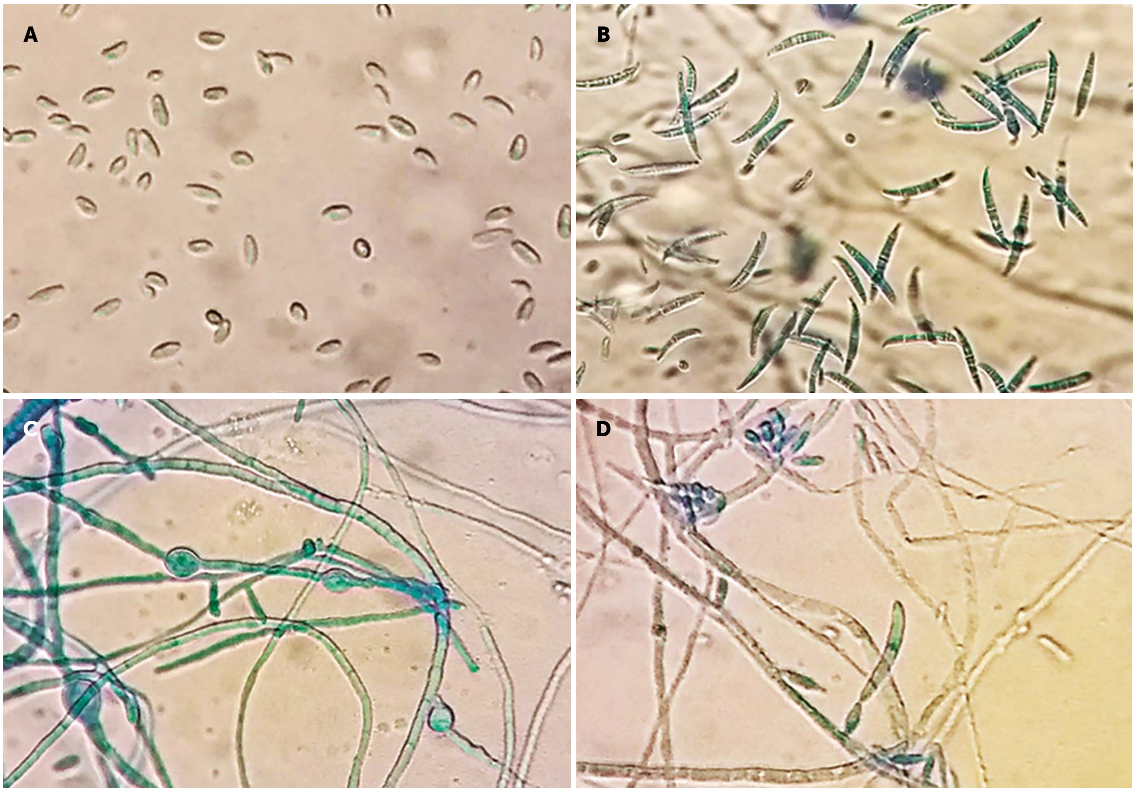

Figure 1. Morphology of *F. oxysporum* f. sp. *niveum* isolated from watermelon plants with vascular necrosis. A) Microconidia, B) macroconidia, C) chlamydospores, D) short phialides.

disease (Correll, 1991; Garcés de Granada *et al*., 2001). *F. o.* f. sp. *niveum* is the special form that is only pathogenic to watermelon, although under greenhouse conditions some isolates of *Fon* can also infect other Cucurbitaceae (Zhou & Everts, 2007).

In watermelon there are numerous varieties with resistance to withering from *Fon*; however, resistance is not universal and in some agricultural regions, the varieties succumb to withering, due to the great physiological specialization of *F. oxysporum* in races (Martyn, 2014). Currently, there are four races of *Fon*: 0, 1, 2 and 3. The four races are present in the United States and in some European countries, although detailed information about the distribution and prevalence of these physiological races in different watermelon producing zones of the world, including Mexico, is still lacking. Race 0 only causes wilt in susceptible cultivars (Sugar Baby), without resistance genes to this disease. Race 1 causes severe wilt in susceptible cultivars and mild to moderate in most of the cultivars that are considered resistant to wilt from *Fon*, as is the case of the Charleston Grey watermelon variety. This race is the one of greatest distribution in the world, and it is present in every production area of the United States (Zhou & Everts, 2007). Race 2 is highly aggressive and causes severe wilt in all the known resistant cultivars; it has been isolated from withered watermelons in Texas, Florida and Indiana, in the United States (Egel *et al*., 2005). Race 3, reported for the first time in the United States, is highly virulent to all the resistant varieties and genotypes of watermelon (Zhou *et al*., 2010).

Symptoms caused by *Fusarium oxysporum* f. sp. *niveum* in watermelon

The initial symptoms of vascular wilt from *F. oxysporum* include an opaque appearance of grey green color, loss of turgidity, and leaf chlorosis, lower growth, wilt and finally plant death. These symptoms are more severe when the infection happens in early seasons of growth. Foliage yellowing generally begins with the inferior leaves and progresses toward the superior part of the plant (Egel & Martyn, 2007). In addition to wilt (Figure 2A), another typical symptom is necrosis and discoloration of the vascular tissue (Figure 2B) that could be observed, especially in the region of the neck or inferior part of

Figure 2. Symptoms caused by *F. oxysporum* f. sp. *niveum* on watermelon plants. A) Wilt under field conditions, B) vascular necrosis in stem, C) wilt on one side of the plant, D) necrosis in the hypocotyl, E) mycelial emerging from infected watermelon plant.

the plant stem, through a longitudinal or transversal cut. Frequently, the wilt symptom can be observed from a single side of the plant (Figure 2C), although as the disease advances the whole plant can wither and die. The watermelon seedlings can also be affected, causing wilt, chlorosis and death of the seedlings, even before the formation of true leaves. In these cases, the hypocotyl of the infected seedlings is seen to be necrotic (Figure 2D) and with fungal mycelium when humidity is high (Figure 2E) (Kleczewski & Egel, 2011).

Biological cycle of *Fusarium oxysporum* f. sp. *niveum*

Vascular wilt caused by *Fon* is a monocyclic disease (Keinath & Hassell, 2014). The initial infection of seedlings generally takes place from chlamydospores that have spent the winter in the soil. The chlamydospores germinate and produce infection hyphae that penetrate the root's cortex, often where lateral roots emerge; wounded roots favor infection by the fungi (Egel & Martyn, 2007).

The progress of the infection by *Fon* in watermelon plants was documented recently by Zhang *et al*. (2015). These authors indicate that, at the beginning of the infection, the fungus spores bind to the root epidermis, germinate and the mycelium grows on the main root, to later penetrate the tissue of the cortex until reaching the xylem vessels, where mycelium grows in both directions and the fungus growth is restricted to the xylem. Within a xylem, the fungus moves upward together with the transpiration current, sporulates and produces microconidia that reach the end of the vessels, where it germinates and mycelium grows in the next vessel, to produce more microconidia (Gordon, 2017). At this point, the characteristic symptom of withering appears as the result from severe hydric stress due to the obstruction of the xylem vessels, product of a combination of the defense response of the host (production of gum, gels and tylose) (Agrios, 2005). As long as the plant is alive, the fungus stays limited to xylem and only when it dies, the fungus sporulates abundantly on the surface of the plant (Di Pietro *et al*., 2003).

F. oxysporum is a pathogen that is easily transmitted through contaminated soil or infected tissue, such as seeds. Tools and machinery contribute to a high percentage of dispersion of the pathogen from one field to another, especially when the implements are used in an infected field and the hygiene of the tools is not verified before using them in a clean field. Air and water also play a role in the propagation of this fungus, especially floods and irrigation water (Joshi, 2018). *F. o.* f. sp. *niveum* could infect watermelon seeds latently, which can be an important source of inoculum and contribute to severe outbreaks of the disease (Petkar & Ji, 2017).

Isolation and diagnosis of *Fusarium oxysporum* f. sp. *niveum*

In the field, the necrosis of vascular tissue is the most characteristic symptom of the disease and which is used for their preliminary diagnosis (Figure 3A). However, the isolation of *F. oxysporum* in non-selective cultivation medium (PDA) or selective (Komada), is necessary for the morphological identification of the pathogen. During isolation, sections of the tissue affected (~1 cm) are disinfected superficially with sodium hypochlorite at 0.5-1%, they were rinsed three times with sterilized distilled water and dried to be placed in Petri dishes with cultivation medium at 28 °C. *Fon* grows rapidly within the next 48 hours in PDA medium and slowly in Komada medium (Figure 3B, 3C). The isolates generally present pink to purple coloration in PDA medium, and a milky aspect in Komada medium. This "traditional" identification of *F. oxysporum* presents the disadvantages of requiring a lot of time, effort and broad knowledge of the fungus for a reliable identification. On the contrary, the molecular identification by PCR presents advantages on the traditional methods of diagnosis, since it is faster, more sensitive and reliable in complement with pathogenicity tests.

Zhang *et al*. (2005) developed a specific PCR assay for the fast and reliable detection of *F. o.* f. sp. *niveum* in tissues of sick plants and soil. These specific primers, Fn-1 (5´-TACCACTTGTTGCCTCGGC-3´) and Fn-2 (5´-TTGAGGAACGCGAATTAAC-3´), amplified a fragment of 327 pb only in *Fon* isolates and not in isolates from other fungi (ascomycetes, basidiomycetes, deuteromycetes and oomycetes). For their part, Lin *et al*. (2010) developed the primers Fon-1 and Fon-2 which amplified a fragment of 174 pb of isolates from *F. o.* f. sp. *niveum*, even from the tissue collected in early stages of the disease development. However, these pairs of primers do not allow identification of *Fon* at the level of race.

Identifying the race of the *Fon* isolates was done based on the virulence toward different watermelon genotypes (Zhou *et al*., 2010). This set of differential plants should include Sugar Baby, Charleston Gray, Calhoun Gray and

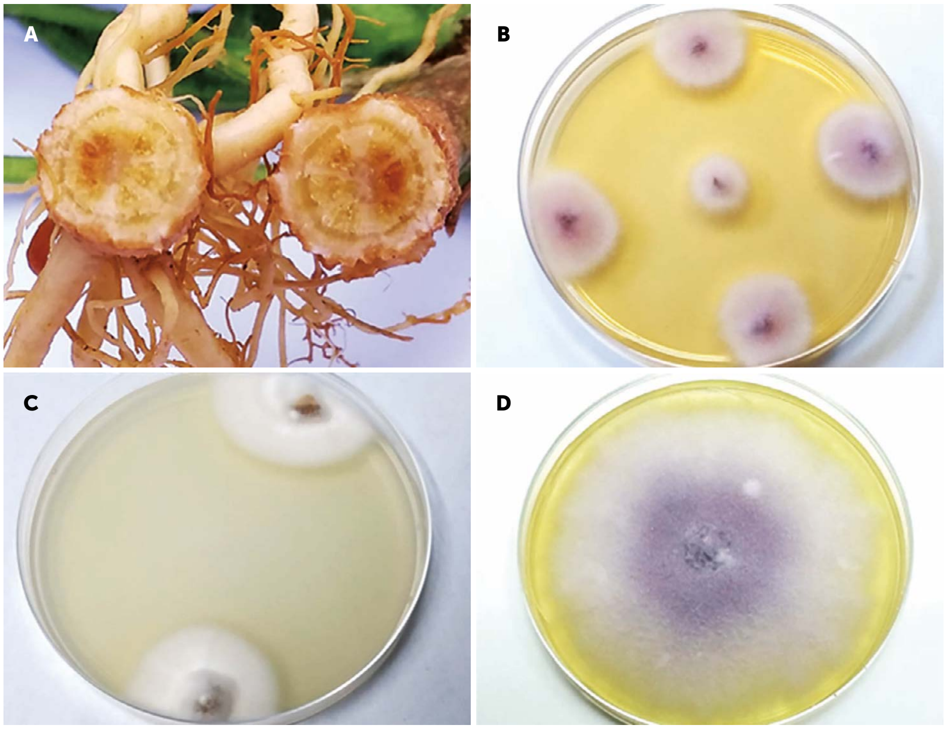

Figure 3. Isolation of *F. oxysporum* f. sp. *niveum* from wilting watermelon plants. A) Vascular necrosis, b) colony in potato dextrose agar (PDA) medium after 72 h of incubation, C) colony in Komada medium after 10 days of incubation, D) colony in PDA medium after 7 days of incubation.

PI-296341-FR. However, Calhoun Gray and PI-296341-FR are not commercially available, which is why the first can be substituted by Allsweet or Dixielee (Zhou *et al*., 2003; Kleczewski & Egel, 2011) and the second by Super Pollinizer-6 (SP-6), developed by Syngenta Seeds, Inc., which derives its resistance to the race 2 of PI-296341-FR (Everts & Himmelstein, 2015).

Management of vascular wilt of watermelon

The management of this disease is difficult when there is not resistant plant material, although there are several methods that individually or combined could help to decrease the disease in a significant way.

Solarization. In watermelon, Martyn & Hartz (1986) reported that solarization of the soil during 30 or 60 days reduces significantly the amount of propagules of *F. oxysporum* f. sp. *niveum* in comparison to the non-solarized soils, thus reducing the total impact of the disease in the susceptible Sugar Baby cultivar.

Grafts. The use of grafted watermelon plants on squash rootstock (*Cucurbita moschata*) was used for the first time at the end of the 1920s in Japan. In Turkey, the use of grafted plants of watermelon reduced in 100% the incidence of withering caused by *Fon* race 0, 1 and 2 (Yetişir *et al*., 2003), and 88% in the United States, compared to the non-grafted plants (Keinath & Hassell, 2014).

Biological control numerous studies have been performed on the control of vascular wilt in watermelon caused by *Fon*; however, most are under laboratory or greenhouse conditions, and very few in the field. Ling *et al*. (2010) reported that the application of a bio-organic fertilizer (*Paenibacillus polymyxa* -SQR21-) reduced between 60-100% the impact of withering caused by *Fon* in experiments in pot and 59-73% under field conditions, when the product was applied to greenhouse seedlings and to soil during field transplant. On the contrary, Himmelstein *et al*. (2014) indicated that the use of the biofungicide Actinovate (*Streptomyces lydicus* -WYEC 108-) for the control of *Fusarium* wilt, did not reduce significantly the disease severity.

Genetic resistance. This method is the most profitable and environmentally safe for the management of *Fusarium* wilt. The cultivars of triploid watermelon (without seeds) are generally more susceptible to wilt from *Fusarium* than diploid cultivars (with seeds) (Zhou *et al*., 2010). At the beginning, management of vascular wilt of watermelon was carried out with the use of diploid cultivars (with resistance to race 1); however, the preference of consumers for triploid watermelons has made these be cultivated increasingly more. Currently, the development of triploid cultivars with high levels of resistance to *Fon* race 1 and 2 (Everts & Himmelstein, 2015) has not been achieved, while for race 3 of *Fon* there is no resistant commercial variety.

Use of agrochemicals. Fungicides represent an additional management option for the control of *Fusarium* in watermelon. In this regard, Everts *et al*. (2014) studied the effect of 14 fungicides for the management of vascular wilt of watermelon caused by *Fusarium*, finding that Protioconazol and methyl thiophanate reduce the damage caused by this pathogen; these agrochemicals were applied on their own or in combination through drip irrigation at 0, 2 and 4 weeks after transplant.

CONCLUSIONS

In Mexico, despite watermelon cultivation being of economic importance, knowledge about *Fusarium wilt* (*F. o.* f. sp. *niveum*) is scarce. In other countries, there have been substantial advances in the understanding of this disease; however, caused by *Fon* continues to be a limiting factor in commercial production. Greater knowledge about the symptoms, the fungus's biology, the presence of races, and the diagnosis and management alternatives of *Fon*, will enable integrating management practices that will allow reducing the losses caused by the disease.

REFERENCES

Agrios, G. N. (2005). Plant Pathology. Fifth edition. Elsevier Inc. 922 p.

Correll, J. C. (1991). The relationship between formae speciales, races, and vegetative compatibility groups in *Fusarium oxysporum*. Phytopathology 81(9): 1061-1064.

Dau, V. T., Burgess, L. W., Pham, L. T., Phan, H. T., Nguyen, H. D., Le, T. V., & Nguyen, D. H. (2009). First report of *Fusarium* wilt of watermelon in Vietnam. Australasian Plant Disease Notes, 4, 3, doi.org/10.1071/DN09001

Di Pietro, A., Madrid, M. P., Caracuel, Z., Delgado-Jarana, J., & Roncero, M. I. G. (2003). *Fusarium oxysporum*: exploring the molecular arsenal of a vascular wilt fungus. Molecular Plant Pathology 4(5): 315-325.

Egel, D. S., Harikrishnan, R., & Martyn, R. D. (2005). First report of *Fusarium oxysporum* f. sp. *niveum* race 2 as causal agent of Fusarium wilt of watermelon in Indiana. Plant Disease 89(1): 108.

Egel, D. S., & Martyn, R. D. (2007). Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. doi: 10.1094/PHI-I-2007-0122-01.

Everts, K. L., Egel, D. S., Langston, D., & Zhou, X-G. (2014). Chemical management of *Fusarium* wilt of watermelon. Crop Protection 66: 114-119.

Everts, K.L., & Himmelstein, J.C. (2015). Fusarium wilt of watermelon: towards sustainable management of a re-emerging plant disease. Crop Protection 73: 93-99.

Garcés de Granada, E., Orozco de Amézquita, M., Bautista, G. R., & Valencia, H. (2001). *Fusarium oxysporum* el hongo que nos falta conocer. Acta Biológica Colombiana 6(1): 7-25.

Gordon, T. R. (2017). *Fusarium oxysporum* and the Fusarium wilt syndrome. Annual Reviews of Phytopathology 55: 23-39.

Himmelstein, J. C., Maul, J. E., & Everts, K. L. (2014). Impact of five cover crop green manures and Actinovate on Fusarium wilt of watermelon. Plant Disease 98:965-972.

Joshi, R. (2018). A review of *Fusarium oxysporum* on its plant interaction and industrial use. Journal of Medicinal Plants Studies 6(3): 112-115.

Kang, S., Demers, J., Jimenez-Gasco, M.M., & Rep, M. (2014). *Fusarium oxysporum*. (pp: 99-119). *In*: Genomics of plant-associated fungi and oomycetes: dicot pathogens. R. A. Dean et al., (Eds.). Springer-Verlag Berlin Heidelberg.

Keinath, A. P., & Hassell, R. L. (2014). Suppression of Fusarium wilt caused by *Fusarium oxysporum* f. sp. *niveum* race 2 on grafted triploid watermelon. Plant Disease 98: 1326-1332.

Kleczewski, N. M., & Egel, D. S. (2011). A diagnostic guide for Fusarium wilt of watermelon. Plant Health Progress. doi:10.1094/PHP-2011-1129-01-DG.

Lin, Y. H., Chen, K. S., Chang, J. Y., Wan, Y.L., Hsu, C. C., Huang, J. W., & Chang, P. F. L. (2010). Development of the molecular methods for rapid detection and differentiation of *Fusarium oxysporum* and *F. oxysporum f.* sp. *niveum* in Taiwan. New Biotechnology 27(4): 409-418.

Ling, N., Xue, C., Huang, Q., Yang, X., Xu, Y., & Shen, Q. (2010). Development of a mode of application of bioorganic fertilizer for improving the biocontrol efficacy to Fusarium wilt. BioControl 55: 673-683.

Martyn, R. D. (2014). Fusarium wilt of watermelon: 120 years of research. Horticultural Reviews 42, 349-442.

Martyn, R. D., & Hartz, T. K. (1986). Use of soil solarization to control Fusarium wilt of watermelon. Plant Disease 70: 762-766.

Michielse, C. B., & Rep, M. (2009). Pathogen profile update: *Fusarium oxysporum*. Molecular Plant Pathology 10(3): 311-324.

Petkar, A., & Ji, P. (2017). Infection courts in watermelon plants leading to seed infestation by *Fusarium oxysporum* f. sp. *niveum*. Phytopathology 107(7): 828-833.

Rana, A., Sahgal, M., & Johri, B. N. (2017). *Fusarium oxysporum*: genomics, diversity and plant-host interaction. (pp: 159-199). Satyanarayana, T. *et al*. (Eds). Developments in Fungal Biology and Applied Mycology. Springer, Singapore.

Servicio de Información Agroalimentaria y Pesquera (SIAP). (2020). Recuperado de: https://nube.siap.gob.mx/gobmx_publicaciones_siap/pag/2020/AtlasAgroalimentario-2020

Yetişir, H., Sari, N., & Yücel, S. (2003). Rootstock resistance to Fusarium wilt and effect on watermelon fruit yield and quality. Phytoparasitica 31(2): 163-169.

Zhang, Z., Zhang, J., Wang, Y., & Zheng, X. (2005). Molecular detection of *Fusarium oxysporum* f. sp. *niveum* and *Mycosphaerella melonis* in infected plant tissues and soil. FEMS Microbiology Letters. 249: 39-47.

Zhang, M., Xu, J. H., Liu, G., Yao, X. F., Li, P. F., & Yang, X. P. (2015). Characterization of the watermelon seedling infection process by *Fusarium oxysporum* f. sp. *niveum*. Plant Pathology 64(5): 1076-1084.

Zhou, X. G., & Everts, K. L. (2003). Races and inoculum density of *Fusarium oxysporum f*. sp. *niveum* in commercial watermelon fields in Maryland and Delaware. Plant Disease 87:692-698.

Zhou, X. G., & Everts, K. L. (2007). Characterization of a regional population of *Fusarium oxysporum* f. sp. *niveum* by race, cross pathogenicity, and vegetative compatibility. Phytopathology 97(4): 461-469.

Zhou, X. G., Everts, K. L., & Bruton, B. D. (2010). Race 3, a new and highly virulent race of *Fusarium oxysporum* f. sp. *niveum* causing Fusarium wilt in watermelon. Plant Disease 94:92-98.

AGRO PRODUCTIVIDAD

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Coffee berry borer (*Hypothenemus hampei* Ferrari) trapping in coffee (*Coffea arabica* L.) with artisan traps at el Paraíso, Guerrero, Mexico

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ABSTRACT

Objective: To evaluate three proportions of alcohol in traps with one and three windows and two different colors to capture *Hypothenemus hampei* Ferrari in *Coffea arabica* L. plants.

Design/methodology/approach: The experiment followed a completely randomized design with a complete factorial arrangement and four replications. From March to July 2007, three mixtures of ethyl: methyl alcohol were evaluated in different proportions (1: 0, 0: 1 and 1: 1). In addition, green and transparent traps were used, designed with a single or three windows. The number of captured coffee berry borers, water loss, attractant evaporation and damaged fruits percentage was evaluated. The data were analyzed through an analysis of variance and a test of means differences (Tukey, $p \leq 0.05$).

Results: The mixture of ethyl: methyl alcohol 1: 1 was the best, with an average catch of 980 trapped - insects week^{-1}. The single window of transparent color traps was the most efficient to avoid water loss, with an average loss of 1,129.79 mL and 905 mL respectively.

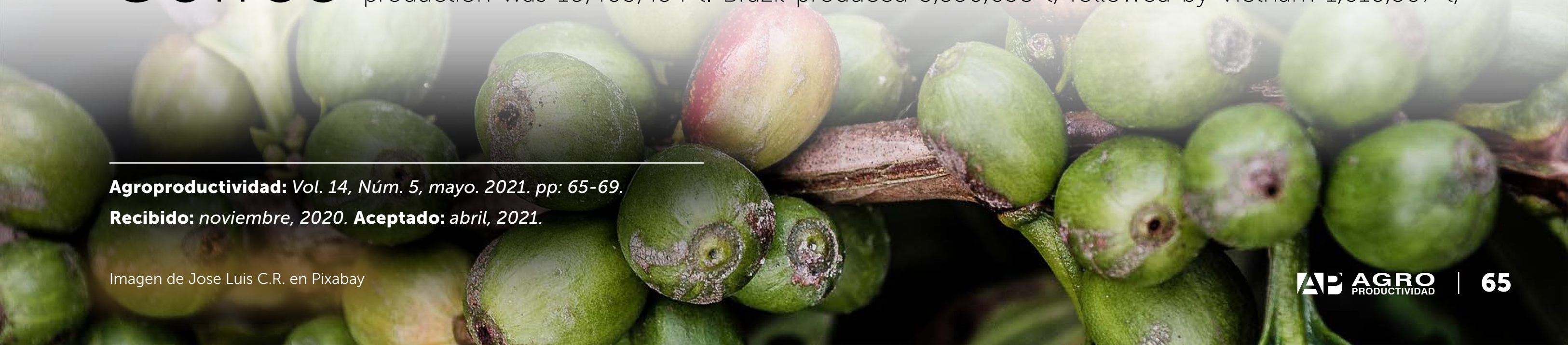
Limitations on study/implications: The design and color of the traps did not influence the capture efficiency and the evaporation of the attractant during the evaluated months. Therefore, it should be further evaluated during other important phenological stages for the crop.

Findings/conclusions: Transparent color traps with a window and 1: 1 ethyl: methyl alcohol were efficient for capturing *H. hampei* and lowering their population.

Keywords: *Hypothenemus hampei* Ferrari, *Coffea arabica* L., attractant, capture and coffee berry borer.

INTRODUCTION

Coffee (*Coffea arabica* L.) is of great economic importance worldwide. In 2018 the average world production was 10,403,454 t. Brazil produced 3,556,638 t, followed by Vietnam 1,616,307 t,



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Indonesia 722,461 t, and Colombia 720,634 t. Mexico ranked eleventh with 158,325 t (FAO, 2020).

In 2018, Mexico registered a planted area of 21,163,051.24 ha, with an average production of 282,569 t and an estimated commercial value of the production of $ 641,026,369.00 (Mexican pesos). The state of Guerrero registered 45,839.05 ha distributed throughout the Costa Grande and Costa Chica regions (SIAP, 2018).

One of the serious phytosanitary problems that coffee presents is the attack of the coffee berry borer (CBB) (*Hypothenemus hampei* Ferrari), which causes losses of up to 80% of production (Benavides and Arévalo, 2002). This pest is endemic to central Africa and distributes in the coffee-growing regions of the world (Rosales *et al*., 1999). Most of the insect's life cycle is feeding on seeds or grains (Barrera, 2002; Barrera, 2013). Due to this, studies continue to develop technologies for its control and the insect´s biology has been studied for better management strategies (Giraldo-Jaramillo *et al*., 2018). Tests have been carried out with chlorantraniliprole, an ingestion insecticide against coleopteran larvae with a new mode of action and low impact with other insects, such as bees. Cyantraniliprole is another insecticide with a mortality effect that affects the behavior of *H. hampei* (Plata-Rueda *et al*., 2019A; Plata-Rueda *et al*., 2019B). In the field, the specimens are captured with attractant traps, where a single trap with methanol-ethanol can capture hundreds of insects per week (Barrera *et al*., 2008) and even with the use of terpenes as repellants (Góngora *et al*., 2020). Celestino *et al*. (2016) evaluated a wide variety of botanical oils, mineral oils and azadirachtin for the control of *H. hampei* but these were not effective.

The objective of this research was to evaluate the effect of three concentrations of alcohol in traps with one and three windows and two different colors to capture *H. hampei* at El Paraíso, municipality of Atoyac de Álvarez, Guerrero, Mexico.

MATERIALS AND METHODS

Experiment location

The research took place in a commercial coffee plantation at El Paraíso, Guerrero, Mexico, located between coordinates 17° 38' 91'' LN, 100° 19' 38'' LW, 1150 m above sea level. The region's climate is A(C)w2 semi-warm subhumid (INEGI, 2012; CESAVEGRO, 2013). The evaluation was carried out from March to July 2007, in a 3 ha area.

Establishment of the experiment and design

The plants under study were marked. The distance between traps was 20 m. A completely randomized design was used in a complete factorial arrangement with four repetitions. The experimental units were the different alcohol proportions in each trap. The traps were placed on a secondary branch at a 1.50 m height; they were marked with a treatment and repetition number to identify and locate it.

Traps crafting

The traps were made with 2 L capacity polyethylene terephthalate-polyester (PET) containers (Figure 1A). For the single window traps (5×5 cm; Figure 1B) a quadrangular cut was made in the middle of the containers. For the three-window trapS, quadrangular holes of the same size were made, distributed in such a way that each window had a barrier in front that would cause an effect of knocking down the insects when they entered the interior of the trap (Figure 1C). The traps were distributed in the orchard as described (Figure 1D). Inside the trap, a dropper with the attractant was installed in the middle of the windows and secured with A 35 cm wire at one end. The mixtures were previously prepared with the proportions of ethyl and methyl alcohol with the help of a syringe and the dropper was filled. With the other end of the wire, the trap was attached to the stem of the plant (Figure 1D).

Treatments

For the evaluation of the variable, three factors were considered: a) Trap design: with one and three windows, b) Trap color: green or transparent, and c) Proportions of ethyl and methyl alcohol: 1: 0, 0: 1 and 1: 1. The combination of these three factors generated 12 treatments shown in Table 1.

Captured CBBs by treatments

The number of captures per treatment was quantified to evaluate the effectiveness of the different treatments. The water from the traps was emptied into a container, separating the captured with a filter.

Water and attractant loss by trap

The water expenditure (mL per week) was quantified with a graduated cylinder when changing the attractant in each trap, to see which lost more water.

The attractant remaining amount per trap was also measured with a graduated cylinder to assess the evaporation loss and calculate its periodicity for each design.

Infestation percentage

Four samples were taken per experimental unit, at a height of 1.5 m at each cardinal point, each with 25 coffee beans, of which the number of brocaded beans was recorded to calculate the percentage of infestation in each assessed plant.

Statistical analysis

A multivariate analysis of variance (MANOVA) was used with a factorial blocks design and the logarithmic transformation of the number of drilled seeds plus one to normalize the residuals. Subsequently, a means comparison was carried out using the Tukey test (α=0.05) to determine which factor levels were the best.

RESULTS AND DISCUSSION

Nineteen records were made of the number of borers captured per installed trap; the evaluations were weekly made.

Figure 1. Traps to capture of *H. hampei* in El Paraíso, Guerrero, Mexico. A) Materials used; B) Trap with one window; C) Trap with three windows; D) Identification and placement of traps.

Captured borers by treatment

The MANOVA results showed that the main effects of trap design, ethanol: methanol ratio and trap color were significant (p=0.002, p=0.002, p=0.001, respectively), but not the three interactions (Table 2).

Table 1. Treatments evaluated for the study of *H. hampei* in El Paraíso, Guerrero, Mexico.

No. Treatment	Trap design	Alcohol	Color of the trap
1	A window	1:0	green
2	A window	0:1	green
3	A window	1:1	green
4	A window	1:0	transparent
5	A window	0:1	transparent
6	A window	1:1	transparent
7	Three windows	1:0	green
8	Three windows	0:1	green
9	Three windows	1:1	green
10	Three windows	1:0	transparent
11	Three windows	0:1	transparent
12	Three windows	1:1	transparent

Regard the capture effectiveness for the coffee borer, it was observed that the ethanol: methanol 1: 1 ratio is the one that recorded the highest capture, an average of 980 trapped insects week 1, followed by 0: 1 and finally 1: 0 (Table 3). These results coincide with those observed by Fernández and Cordero (2005), where they evaluated different attractants and their methyl and ethyl alcohol treatment was superior to the others, with average 400 captured adults per week.

Regard the trap color, the transparent color captured a greater number than the green color. Finally, it is

Table 2. Analysis of variance of the variable number of coffee berry borer per trap.

Source of variation	Pr>F	Significance
Design* Attractive proportions	0.4506	ns
Design*Color	0.4272	ns
Attractant proportions *Color	0.6480	ns
Design*Attractive proportions *Color	0.9624	ns

* P≤0.05 ** P≤0.01 ns: not significant

observed that the design with three windows is better than the single window, which concurs with that reported by Barrera *et al*. (2008), who evaluated two types of traps (ETOTRAP® and ECOIAPAR®) with a mixture of methanol: ethanol in a 3: 1 ratio, respectively, concluded that the design of the trap influences the attraction efficiency.

Table 3. Efficiency of the proportions of alcohol in the capture of *H. hampei*, in El Paraíso, Guerrero, Mexico.

Proportions ethanol:methanol	Number of coffee berry borer
1:1	980.00 a
0:1	473.60 b
1:0	143.6 c

Tukey's test (p<0.05), values with the same letter in the column are not significantly different.

Table 4. Water loss in mL per trap depending on the number of windows.

Design	Water loss (mL)
Three windows	1,997.38 a
A window	1,129.79 b

Tukey's test (p<0.05), values with the same letter in the column are not significantly different.

The traps used in this study are an excellent tool to lower *H. hampei* populations weekly and can be part of an integrated management strategy with other different techniques or tools because insecticide tests with new action pathways against larvae have been carried and have shown to be friendly with parasitoid insects, predators and pollinators (Plata-Rueda *et al*., 2019A). Insecticides such as Ciantraniliprole have lethal and sublethal effects that affect their behavior (Plata-Rueda *et al*., 2019B); and terpenes, botanical and mineral essential oils with insecticidal and repellent effects (Celestino *et al*., 2016; Etztli *et al*., 2019; Góngora *et al*., 2020) or the use of *Bacillus thuringiensis* for first instar larvae (López-Pazos *et al*., 2009).

Water loss per trap

It was observed that the weekly water loss by evaporation presented differences according to the design (Pr>F=0.0001) and the color (Pr>F=0.0415) of the trap, as well as the interaction of these (Pr>F=0.0121).

The highest water loss occurred in the three window traps (1,997.38 mL per week) than in the traps with single window ones (1,129.79 mL per week) (Table 4).

The observed differences in water loss were according to the color and the design of the traps. The transparent color presented less evaporation or loss of water (1,501.63 mL per week), while the green traps lost 1,625.54 mL per week. This can be attributed to the conditions of the coffee plantation, since, in shaded coffee plantations, the relative humidity is higher than in those exposed to the sun (PROCAFE, 2013). Regard the water loss in traps due the number of windows, differences were observed between the treatments, where the three windows design is statistically the same and different from the treatments of one window. Noting that the three window traps had a greater water loss (1,919.5 to 2,090.5 mL per week), while the single window traps recorded lower water loss (905.0 to 1,3056.5 mL per week) (Table 5).

Loss of attractant by trap

This estimation was made with the amount of the mixture per dropper at the time of installation of the traps of each of the treatments and the difference in the second reading at the time of removing the dropper from the trap. No difference was observed in the ethanol-methanol ratios, design and color of the trap, as well as their interactions. Unlike other research, when evaluating alcoholic attractants in artisanal traps to capture adult female coffee borers (*H. hampei*), higher consumption of attractant was observed in the methanol: ethanol 1:1 treatment, the methanol-ethanol 3:1 treatment recorded higher captures than other treatments and a lower attractant consumption (Espinoza, 2013).

Table 5. Interactions of the design with the color of the trap in the loss of water.

No. treatment	Trap (No. Windows)	Color of the trap	Water loss (mL)
1	1	green	1,219.3 c
2	1	green	1,235.5 c
3	1	green	1,356.5 bc
4	1	transparent	1,106.0 c
5	1	transparent	905.0 c
6	1	transparent	959.5 c
7	3	green	2,047.0 a
8	3	green	1,970.0 a
9	3	green	1,928.0 a
10	3	Transparent	2,029.3 a
11	3	Transparent	2,090.5 a
12	3	Transparent	1,919.5 ab

Tukey's test (p<0.05), values with the same letter in the column are not significantly different.

Infestation percentage

The lowest infestation is observed in the 1:0 ethyl and methyl alcohol mixing ratio, with a mean of 0.9125. The highest infestation was recorded with the 1:1 ratio of ethyl and methyl alcohol of 1.4375, respectively (Table 6).

It should be noted that CBBs catch is not directly proportional to the infestation percentage, because the attractant attracts CBBs from neighboring properties with high infestations, usually those abandoned.

Table 6. Level of infestation by *H. hampei* according to the ethyl: methyl alcohol ratios and the percentage of damaged fruits.

Proportion (ethyl:methyl)	Infestation level (%)
1:1	1,4375 a
0:1	1,2500 ab
1:0	0.9125 b

Tukey's test ($p<0.05$), values with the same letter in the column are not significantly different.

CONCLUSIONS

The ratio of ethyl alcohol: methyl 1:1 presented the highest capture rate of the coffee berry borer (*H. hampei* Ferrari). The trap color does not influence the *H. hampei* capturing, the evaporation of the attractant and the level of infestation. The traps with a single-window and a transparent color were the ones that recorded the least water loss.

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REFERENCES

Barrera, J.F. (2002). La Broca del Café: Una plaga que llego para quedarse. Plagas del Café en Chiapas. Colegio de la Frontera Sur. 17-20.

Barrera, J.F., Herrera, J., Chiu, M., Gómez, J. y Valle, M.J. (2008). La trampa de una ventana (ECOIAPAR) captura más Broca del Café *Hypothenemus hampei*, que la trampa de tres ventanas (ATOTRAP). Entomología Mexicana. 7: 619-624.

Barrera, J.F. (2013). Ficha técnica Broca del Café *Hypothenemus hampei* SENASICA-Dirección General de Sanidad Vegetal.

Benavides, P. y Arévalo, M. (2002). Manejo Integrado: una estrategia para el control de la broca del café en Colombia. CENICAF. 53(1): 39-48

Celestino, F.N., Pratissoli, D., Machado, L.C., Santos, H.J., Queiroz, V.T. & Mardgan, L. (2016). Control of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae: Scolytinae) with botanical insecticides and mineral oils. Acta Scientiarum. Agronomy, 38(1), 1-8. https://doi.org/10.4025/actasciagron.v38i1.27430

CESAVEGRO, Comité Estatal de Sanidad Vegetal de Guerrero. (2013). Sistema de Información de Campañas Fitosanitarias (SICAFI). Campaña contra Broca del Café. Consulta realizada en https://cesavegro.org.mx/plagas-del-cafeto/.

Espinoza, A.F. (2013). Evaluación de Atrayentes Alcohólicos en trampas artesanales para la captura de hembras adultas de broca del café *Hypothenemus hampei* (Ferrari) en la Estación Experimental de San Pedro de la loma-Coroico. Tesis de grado para obtener el título de: Licenciatura en Ingeniería Agronómica. La Paz-Bolivia.

Etztli, I.M., Reyes, S.F., Eliete, M.P., Claudinei, A.F., Plata, A.B., Picanço, M.C. & Barbosa, C.A. (2019). Eucalyptus resinifera essential oils have fumigant and repellent action against *Hypothenemus hampei*. Crop Protection 116: 49-55. https://doi.org/10.1016/j.cropro.2018.09.018.

FAO, Food and Agriculture Organization (2020). FAO: Estadísticas. http://www.fao.org/faostat/es/?#data/QC. Consultada el 08 de febrero del 2020.

Fernández, S. y Cordero, J. (2005). Evaluación de atrayentes alcohólicos en trampas artesanales para el monitoreo y control de la broca del café, *Hypothenemus hampei* (Ferrari). BIOAGRO. 17(3): 143-148.

Giraldo-Jaramillo, M., Garcia, G.A. & Parra, R.J. (2018). Biology, Thermal Requirements, and Estimation of the Number of Generations of *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Curculionidae) in the State of São Paulo, Brazil, Journal of Economic Entomology, 111(5): 2192–2200. https://doi.org/10.1093/jee/toy162

Góngora, C.E., Tapias, J., Jaramillo, J., Medina, R., Gonzalez, S., Casanova, H., Ortiz, A. & Benavides, P. (2020). Evaluación de compuestos terpénicos volátiles repelentes al barrenador del café, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae). J. Chem. Ecol. 46: 881–890. https://doi.org/10.1007/s10886-020-01202-5

INEGI (2012). Instituto Nacional de Estadística, Geografía e Informática. Gobierno del Estado de Guerrero, Anuario Estadístico del Estado de Guerrero. 601.

López-Pazos, S.A., Cortázar, J.A. & Cerón, S.A. (2009). Cry1B and Cry3A are active against *Hypothenemus hampei* Ferrari (Coleoptera: Scolytidae). Journal of Invertebrate Pathology 101(3): 242-245.

Plata-Rueda, A., Martínez, L.C., Rodrigues, N.C., Cola, J., Sena, M.E., Serrão, J.E., Carvalho, R.N. & Lemes, F. (2019A). Chlorantraniliprole–mediated effects on survival, walking abilities, and respiration in the coffee berry borer, *Hypothenemus hampei*, Ecotoxicology and Environmental Safety, 172: 53-58. https://doi.org/10.1016/j.ecoenv.2019.01.063.

Plata-Rueda, A., Martínez, L.C., Da Silva, B.K., Zanuncio, J.C., Fernandes, M.D., Guedes, R.N. & Fernandes, F.L. (2019B). Exposure to cyantraniliprole causes mortality and disturbs behavioral and respiratory responses in the coffee berry borer (*Hypothenemus hampei*). Pest Management Science. https://doi.org/10.1002/ps.5358

PROCAFE (2013). Fundación Salvadoreña para Investigaciones en Café. Consulta realizada en: http://www.procafe.com.sv/menu/Generalidades/CondicionesAgroecologicas.htm.

Rosales, M.M., Silva, A. y Rodríguez, G.G. (1999). Estrategia para el manejo integrado del minador de la hoja y la broca del fruto del café (en línea). FONAIAP.

SIAP, Servicio de Información Agroalimentaria y Pesquera. (2018). www.siap.gob.mx. Consultada el 25 de febrero, 2018.

https://doi.org/10.32854/agrop.vi.1634

Standardization of smoked and natural sausage manufacturing processes and shelf-life determination

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ABSTRACT

Objective: To determine the shelf life of sausage under the natural and smoked processes to standardize their manufacturing process, evaluate their physicochemical and microbiological quality using a mathematical model of order zero chemical kinetics.

Methodology: The sausage manufacturing process was standardized, and two cooking and preservation methods were applied: boiling and smoking in oak wood. For the shelf-life analysis, a partially staggered sampling was used. The product samples were kept refrigerated (2 to 6 °C, for 7 weeks), and physicochemical and microbiological analyses were carried out on them every week. A mathematical model based on order zero chemical kinetics was used with the obtained results to determine the shelf life of the processed products.

Results: The shelf life of sausages depends on the applied preservation process; in the case of the traditional (hot water) process, the result was 33 d, and increased to 56 d in the smoked and cooked with dry heat, due to the water content of each product, as well as the smoking antimicrobial action.

Keywords: meat products, shelf life, standardization.

INTRODUCCIÓN

Meat can form part of a balanced diet, providing beneficial and valuable nutrients for the health. Meat and meat products contain important protein levels, vitamins, minerals and micronutrients, essential for growth and development. Meat processing represents an opportunity to add value, reduce prices, promote food safety and extend shelf life. This in turn generate increased household income and improved nutrition (FAO, 2014). Meat consumption in some industrialized countries is high, in developing countries the *per capita* meat consumption of less than 10 kg, and considered insufficient and often causes undernourishment

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and malnutrition. It is been estimated that more than 2 billion people in the world suffer from essential vitamin and mineral deficiencies, particularly vitamin A, iodine, iron and zinc. Such deficiencies occur when people have limited access to micronutrient-rich foods such as meat, fish, fruits and vegetables. Most people with micronutrient deficiencies live in low-income countries and are generally deficient in more than one micronutrient. HIV/AIDS infected communities, women and children are particularly in need of highly nutritious foods such as meat. Meat processing technologies are a series of techniques and procedures used in the manufacturing of processed meat products. Meat processing makes maximum use of meat and slaughter by-products. Animal tissues, muscle meat and fat are their main ingredients. Occasionally other tissues such as viscera, skin and blood are used, which are complemented with ingredients of vegetable origin. All processed meat products on the market have been physically or chemically treated, these treatments go beyond simple cuttings of meat and its subsequent preparation as cooked meat dishes. Modern meat processing includes a series of physical and chemical treatment methods. Although only one can be used, in general, a combination of several methods is used. Modern meat product processing techniques result in safer products, which together with Good Manufacturing Practices (GMP's) generate products with a longer shelf life, which allows reducing the chemical additives used under the conditions established by the WHO and the NOM of each of the processed products. The shelf life is a study performed on each of the products to determine the time it takes for the product to reach the sanitary specifications that exceed permissible limits, which allows establishing an expiration date for each of the products. Based on the above, the shelf life of sausages was determined under natural and smoked processes, to standardize their manufacturing process, evaluate their physicochemical and microbilogical quality using a zero-order mathematical model of chemical kinetics.

MATERIALS AND METHODS

The meat products in produced a workshop and analyzed for this study were: natural and smoked sausages, vacuum-packed, from only pork leg meat, acquired from a local distributor. The sausage formulations were based on the specifications established in NMX-F-065-1985. Their evaluation period was of three months, and a partially staggered sampling was designed for shelf-life analysis by analyzing every 7 days the physicochemical characteristics of the products following the Mexican Standards (Table 1).

The microbiological evaluation of the products was carried out following the specifications in the NOM-110-SSA1-1994. Standard for the preparation and dilution of food samples for microbiological analysis and NOM-092-SSA1-1994, goods and services. standard for method for aerobic bacterial plate count. These analyses were performed every 15 d. Once the results of the physicochemical and microbiological analyses were obtained, a mathematical zero-order method of the chemical kinetics was applied to determine the days of shelf life of each of the products. This method was performed in Excel® 2018 spreadsheet, and the results were plotted in a scatter diagram and obtained by the least-squares method the linear regression obtaining the equation of the line and from this, take the values of the intercept with the x-axis, the slope of the line and the value of the correlation factor of the variables.

Table 1. Applied physicochemical analysis methods.

Parameters	Standard methods
pH	NMX-F-317-NORMEX-2013 Determination of pH in food and non-alcoholic beverages, potentiometric method.
Titratable acidity	NMX-F-102-NORMEX-2010 Determination of titratable acidity in foods.
Water activity a_w	NMX-F-621-NORMEX-2008 Determination of water activity in food.
% Moisture content	NMX-F-428-1982 Determination of moisture in food. Thermobalance method.

With these values and the maximum or minimum limit of each of the analyzed specifications, the days of shelf life of the products were calculated. The correlation factor is a determining factor to know which is the limiting variable in this study; this value should be as close to 1.0 as possible to values used for our analysis. If the correlation factor value is low, it means that the product shows stability in the assessed variable and therefore, does not represent a limiting factor that affects the shelf life of the product.

RESULTS AND DISCUSSION

Determination of natural sausage shelf life

The physicochemical analyses are shown in Table 2.

Table 2. Results of physicochemical analysis of natural sausage.

Storage days	pH	Titratable acidity [1]	Aw	Moisture content (%)
0	6.41	0.45	0.9853	65.7
7	6.44	0.55	0.9895	54.4
14	6.46	0.55	0.9886	68.5
21	6.45	0.60	0.9920	69.1
28	6.43	0.65	0.9934	46.0

The product increases its water activity due their cooking method is hot water and having a minimum number of additives, the water migrates from the product and can be observed in the product packaging. Consequently, it has more available water for microbiological decomposition, thus represent a limiting factor for the shelf life of this products.

With these results, a scatter plot was constructed for each of the variables individually, to obtain the equation of the line, and thus to determine the values of their slope, their intercept with the x-axis and the correlation factor. Figure 1 shows that the correlation factor is low, which indicates the pH stability in the product, so this is not a determining factor for the shelf life of the natural sausage.

Figure 2 shows that the acidity value increases, so it is a factor that limits the shelf life of the products.

To determine the shelf life of the natural sausages, a value of 0.70 acidity was taken as a limit, and along with the values of the intercept and the slope, the time in days was calculated.

$$t = \frac{A_e - A_o}{k}$$

$$t = \frac{0.70 - 0.47}{0.0064}$$

t=36 days of shelf life for the natural sausage. Figure 3 shows the linear regression for water activity to obtain the slope and intercept values.

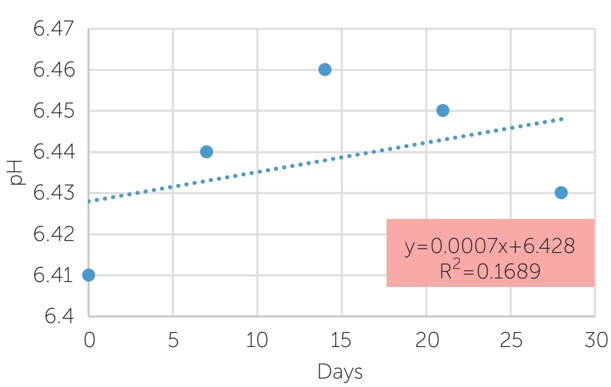

Figure 1. Linear correlation graph of the pH in the natural sausages.

Performing the operations, we obtain:

$$t = \frac{A_e - A_o}{k} \quad (4)$$

$$t = \frac{0.995 - 0.986}{0.0003}$$

t=30 days of shelf life for natural sausages.

According to the correlation factor of humidity analysis (very low value), it does not represent a limiting factor for the product's shelf life, although it does regard the a_W values, due product's humidity decreases. Regard the sanitary quality of the product, the results of microbial, analysis (mesophilic aerobic) are shown in Table 3.

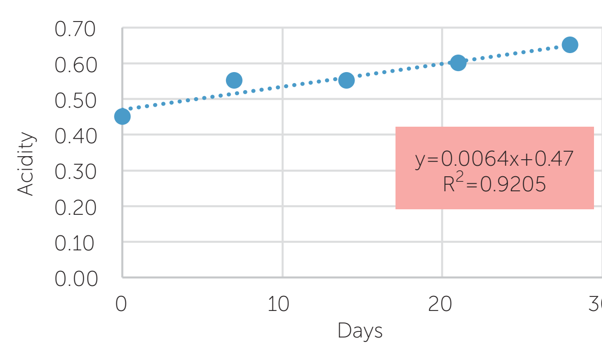

Figure 2. Linear correlation graph of the acidity of natural sausages.

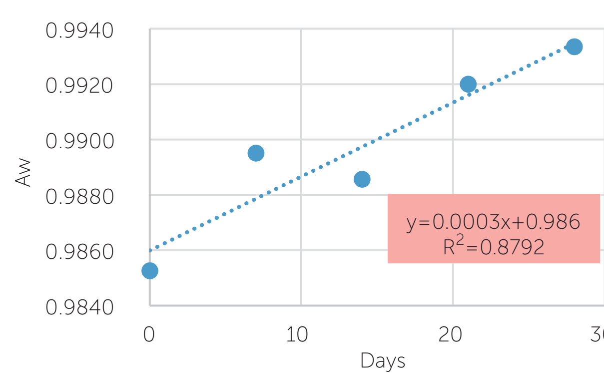

Figure 3. Linear correlation plot for the water activity in natural sausages.

With these results, the linear correlation shown in Figure 4 was performed.

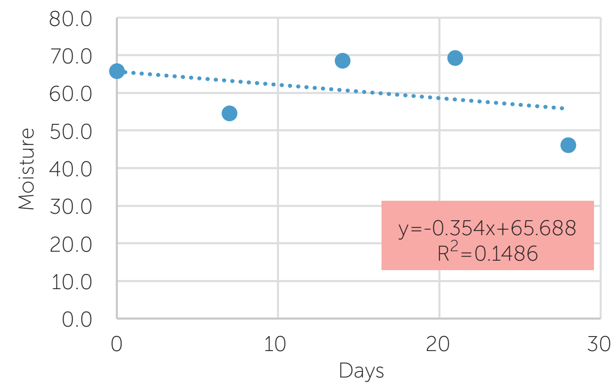

Figure 4. Linear correlation graph of the percentage moisture content in natural sausages.

Agree to Figure 5, Microbial growth increases through time, which indicates it will cause the decomposition of the product reducing shelf life. The obtained data of microbial analysis and according to the sanitary specifications of standard NMX- NMX-F-065-1985. Specifications, it was considered a maxim limit value of 200,000 CFU/g. With these values and following the shelf life formula with a order zero chemical kinetics, the shelf life of the natural sausage was obtained:

$$t = \frac{A_e - A_o}{k}$$

$$t = \frac{200{,}000 - 12{,}000}{6{,}314.3}$$

t=34 days of shelf life for natural sausages.

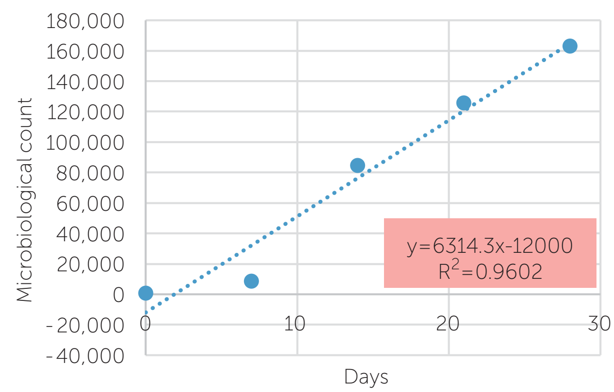

Figure 5. Linear correlation graph of microbiological analysis of natural sausages.

The shelf life of natural sausage it's was obtained in relation to the results of the analyses carried out on the natural sausage, an average was achieved of this research, as seen in Table 4.

Table 3. Results of the microbiological analysis of sausage.

Storage days	Microbiological count (UFC*/g)
0	500
7	8,500
14	84,500
21	125,500
28	163,000

Table 4. Results of the days of shelf life of natural sausages.

Evaluated parameters	Shelf life (days)
Titratable acidity	36
Water activity	30
Microbiological count	34
Average value	33

Shelf life of smoked sausage

The results of the physicochemical analyses performed on the smoked sausage samples are shown in Table 5.

According to the results physicochemical analyses, linear relationship graphs for each of the parameters were prepared to obtain the slope data, their intercept and correlation factor to determine the days of shelf life of the smoked sausages. Figure 6 shows the correlation of the pH values in the natural sausage samples. According to the correlation factor, there is a positive relationship, so that the shelf life of the product is affected.

Table 5. Results of physicochemical analysis of smoked sausages.

Storage days	pH	Titratable acidity [1]	Aw	Moisture content (%)
0	6.09	0.6	0.9545	48.9
7	6.53	0.55	0.9769	50.9
14	6.61	0.65	0.9549	49.1
21	6.91	0.7	0.94825	51.55
28	6.67	0.65	0.9559	51.8

According to the slope values, intercept and pH limit value in the product, the days of shelf life were obtained:

$$t = \frac{A_e - A_o}{k}$$

$$t = \frac{7 - 6.254}{0.022}$$

t=34 days of shelf life for smoked sausage.

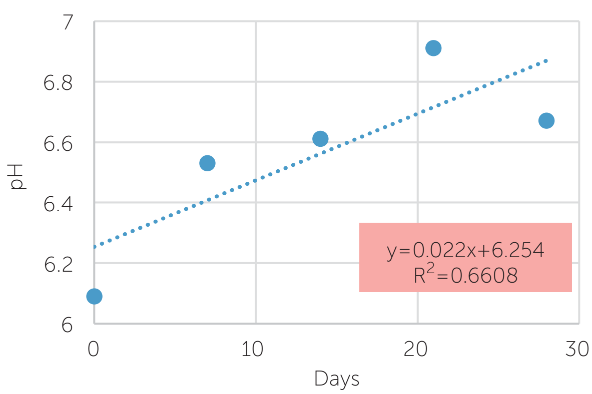

Figure 6. Linear correlation graph of the pH of smoked sausages.

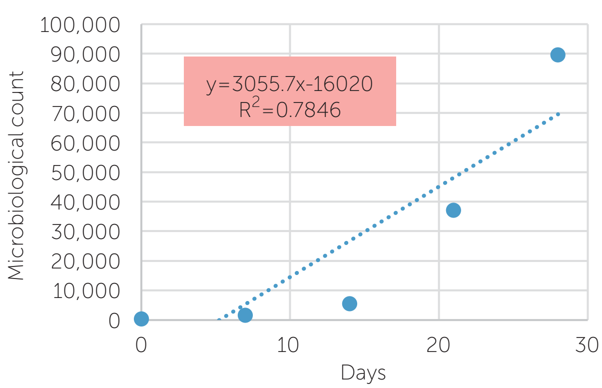

Figure 7. Linear correlation of smoked sausages acidity.

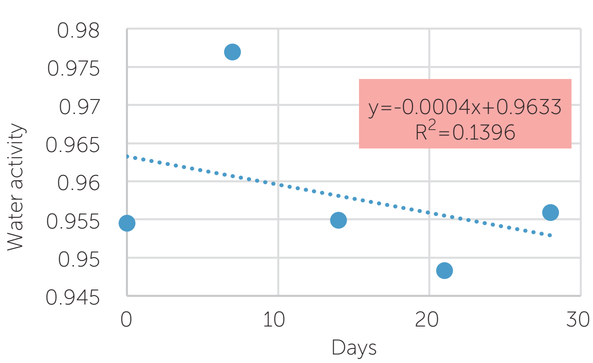

Figure 9. Linear correlation graph of the moisture percentage of smoked sausages.

Figure 7 indicates the linear correlation of the acidity behavior values of the product samples regarding time. The trend of the line indicates that the change in this parameter is small (value of the correlation factor), therefore, this variable is not a limiting factor for the product's shelf life.

Figure 8 shows the trend of the results of the water activity analysis determined to the smoked sausage samples.

There is no significant change in the correlation factor in the results, so it will not limit the shelf life of the product. Figure 9 shows the behavior of the results of the moisture percentage analysis applied to the smoked sausage samples.

According to the correlation factor, the moisture of the sausage is a factor that limits its shelf life, so it was analyzed this value, according to humidity values and its interrelation with time (Figure 10).

$$t = \frac{A_e - A_o}{k}$$

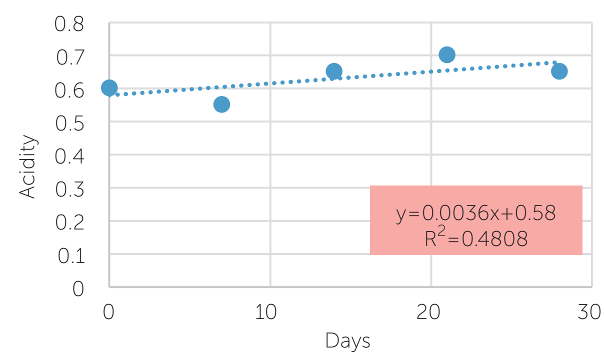

Figure 8. Linear correlation of the water activity of smoked sausages.

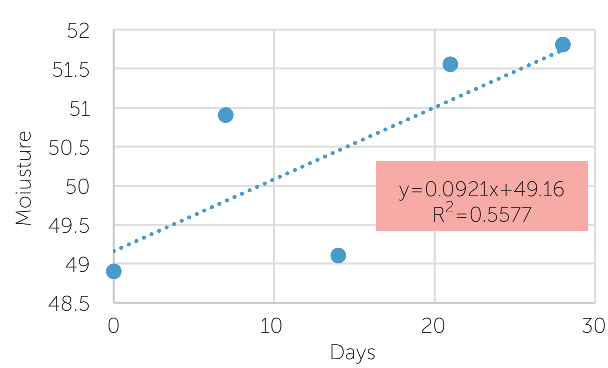

Figure 10. Linear correlation of microbiological analysis of smoked sausage.

$$t = \frac{55 - 49.16}{0.5577}$$

t=63 days of shelf life for the smoked sausages.

Table 6 shows the results of the aerobic mesophilic analyses performed on the smoked sausage samples.

Table 6. Microbiological results of smoked sausages.

Storage days	Microbiological count (UFC*/g)
0	300
7	1,500
14	5,500
21	37,000
28	89,500

With these data, a linear regression graph was made (Figure 10).

Microbiological growth in the samples of the natural sausages was a limiting factor in this product, for which reason its shelf life was calculated. For this purpose, the slope and intercept data were obtained, and the maximum value of 200,000 CFU/g of aerobic mesophiles was used.

$$t = \frac{A_e - A_o}{k}$$

$$t = \frac{200{,}000 - 16020}{3{,}055.7}$$

t=71 days of shelf life for the smoked sausages.

The values of shelf life of the product in relation to the results of the analyses performed on the smoked sausage are obtained from an average to determine the value in the study, as shown in Table 7.

Table 7. Results of the days of shelf life of smoked sausages.

Evaluated parameters	Shelf life (days)
pH	34
Moisture content (%)	63
Microbiological count	71
Average value	56

CONCLUSIONS

The natural sausage reported exhibited changes in physicochemical parameters, which could be seen in its appearance since it suffered water loss due to the small number of additives for water retention. As for their sanitary quality, standard NMX-F-065-1985 specifies a maximum limit of 500,000 CFU/g, it was decided to use a limit of 200,000 CFU/g, given that it is desirable to offer a higher quality than that of commercial sausages. With these parameters, a shelf life of 33 days was determined for the natural sausages, stored in refrigerated conditions (4 °C) in vacuum bags. The smoked sausages were processed in a similar way to the natural sausage; however, their cooking is done it was conducted with dry heat while the natural smoking process is done with particular woods. Therefore, the physicochemical parameters such as water activity and humidity are not affected and their sanitary quality is better than the natural sausage, which increases the product's shelf life to 56 days. In the natural sausages, due to the physical quality of the products in its packaging, it is also proposed to use an additive that retains water in the system and improves this undesirable aspect for the consumer. Due to this modification, it will be necessary to perform the shelf-life estimation in the future.

REFERENCES

Alvarez Calvache F., Santamaría D., Lara A. (2016). Análisis del tiempo de vida útil en la elaboración de mermelada de higuerón (*Cucúrbita Odorífera* Vell) con zanahoria (*Daucus Carota*). Revista chilena de nutrición, 43 (3), http://dx.doi.org/10.4067/S0717-75182016000300009

Carrillo Inungaray M.L., Reyes Munguía A. (2013). Vida útil de los alimentos. Revista Iberoamericana de las ciencias biológicas y agropecuarias. 2 (3).

FAO (2014). Departamento de agricultura y protección al consumidor. Consumo de carne. www.fao.org/ag/againfo/themes/es/meat/background.html

FAO (2014). Departamento de agricultura y protección al consumidor. Grupo de productos. www.fao.org/ag/againfo/themes/es/meat/Processing_product.html

FAO (2014). Departamento de agricultura y protección al consumidor. Tecnologías de elaboración. www.fao.org/ag/againfo/themes/es/meat/Processing_techn.html

García Valencia F. E., Millán Cardona L. J., Jaramillo Garcés Y. (2008). Estimación de la vida útil fisicoquímica, sensorial e instrumental de queso crema bajo en calorías. Revista Lasallista de Investigación. 5 (1), pp. 28-33.

Giraldo Gómez I. (1999). Métodos de estudio de vida de anaquel de los alimentos. Universidad Nacional de Colombia.

González González G., Pirovani M. E., Piagentini A.M. (2016). Cinética de cambios sensoriales y vida de anaquel de carambola mínimamente procesada. Revista fitotecnia mexicana, 39 (4).

Prandal, O., Fisher A., Schmidhofer T., Jurguen H. (1992). Tecnología e higiene de la carne. Ed. Acribia. España.

Wirth F. (1999). Tecnología de los embutidos escaldados. Ed. Acribia. España.

https://doi.org/10.32854/agrop.v14i05.1859

Assessing the benefits of a fertilizers program for the welfare on the corn (*Zea mays* L.) market in Chiapas, Mexico

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ABSTRACT

Objective: To assess the impact that the Fertilizers Program for the Welfare would have on corn production and consumption in the state of Chiapas, Mexico.

Methodology: A spatial equilibrium model applied to the corn market in the state of Chiapas for 2018 was used. To assess the benefits of policy implementation, producer and consumer surpluses were calculated with and without the Fertilizers Program.

Results: The results indicate that the implementation of the program increases production and consumption of corn by 171 and 115 thousand tons, which would represent an increase of 13 and 8.3%, compared to the base model with no program. The producer and consumer surpluses would increase by 6 and 4.5 million pesos (MXN), which would represent an increase of more than 10 million pesos in the welfare of society in the state.

Study limitations/implications: The positive effects on corn producers and consumers imply that the policy should be extended to all those regions that have the potential to increase production via their yield.

Conclusions: The program has positive effects on the corn market by increasing corn production, consumption and societal welfare.

Keywords: corn market, Fertilizers Program, producer surplus.

INTRODUCTION

As a staple food that makes up the diet of urban and rural consumers, corn (*Zea mays* L.) is of economic, social and cultural importance in the state of Chiapas. According to the Servicio de Información Agroalimentaria y Pesquera (SIAP, 2018b) corn is grown on 665 thousand hectares, 80% of the state agricultural area in Chiapas.

According to SIAP data (2018b), for the 2008/10-2016/18 period, corn production registered a drop of −11.6% going from 1,625 to 1,148 thousand t, which represented an average annual decrease of −0.12%. The cause for this drop in production was the decrease in the harvested area, but above all, the decrease in yield. During the period, the harvested area decreased by −1.9%, while yield fell by −9.9%, from 2.3 to 1.8 t ha^{-1} (Table 1).

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During 2008, the state of Chiapas was in fourth place among the 32 corn producing states in Mexico and is currently in ninth place.

The above data indicate that the decline in corn production in the state is largely due to the drop in productivity per hectare. In response to this problem, the Federal Government proposes, through the National Development Plan 2019-2024, the delivery of fertilizers to increase productivity at the countryside (SEGOB, 2019). The usage of fertilizers in agriculture is visualized as the mechanism to increase crop yields to increase the agricultural production (SADER, 2019).

Globally, cereal production is projected to increase to 3053 million t in 2028 (OECD-FAO, 2019), and corn production is expected to have the largest increase compared to other cereals. This projection would be achieved with the efficient use of inputs, such as fertilizers, improved seeds, and other agricultural chemicals.

According to data from the Servicio de Información Agroalimentaria y Pesquera (Agrifood and Fisheries Information Service, SIAP, 2013), currently, the usage of fertilizers is responsible for 50% of the world's food supply. Agrifood and Fisheries Information Service estimates indicate that out of the 22 million hectares cultivated in Mexico, only 68% use fertilizers; that is, in 15 million hectares (CEDRSSA, 2019).

At the beginning of the current federal administration, in Mexico, the Fertilizers Program for the Welfare was created by the Secretaria de Agricultura y Desarrollo Rural (Ministry of Agriculture and Rural Development, SADER), which consists in delivering fertilizers in strategic service areas for food production, within which there are the states of Campeche, Chiapas, Guerrero, Quintana Roo, Oaxaca, Tabasco, Yucatán and Veracruz. The Program consists of the delivery of fertilizer packages of up to 450 kilograms of nitrogen and phosphate (SEGOB, 2019).

Table 1. Corn production, area, and yield in Chiapas, 2008-2018.

Year	Production thousands of t	Area thousands of ha	Yield t ha^{-1}	Value millions of $
2008	1,625	693	2.3	4,487
2009	1,218	685	1.8	3,697
2010	1,394	687	2.0	4,348
2011	1,554	706	2.2	6,210
2012	1,405	705	2.0	5,523
2013	1,529	701	2.2	4,858
2014	1,188	664	1.8	3,830
2015	1,068	658	1.6	3,843
2016	1,302	684	1.9	4,699
2017	1,297	690	1.9	4,675
2018	1,148	651	1.8	4,500
Average 2008/10	1,413	688	2.1	4,178
Average 2016/18	1,249	675	1.8	4,624
GR 2008/10-2016/18	−11.6	−1.9	−9.9	10.7
AAGR 2008/10-2016/18	−0.12	−0.02	−0.10	0.11

GR=growth rate; AAGR=annual average growth rate; Source: data from SIAP (2018).

The first beneficiaries states of the Program were the southern states of the country, starting with the state of Guerrero. In 2019 the Program supported 280,000 low-income producers, representing a cultivation area of 500,000 hectares (Jiménez, 2020). Institutions such as Seguridad Alimentaria Mexicana (SEGALMEX) participate in the operational mechanics of the program, who were responsible for: a) enabling distribution centers for the reception and storage of fertilizer; b) verifying the identity of the producers and c) delivering the fertilizer to the producers subject to support. Petróleos Mexicanos (PEMEX) was the sole supplier of the fertilizers (SEGOB, 2020). Considering the economic and social importance of corn production in the state of Chiapas, the objective of this research was to evaluate the impact of the Fertilizers Program on the corn production and consumption.

MATERIALS AND METHODS

To achieve the research objective, a spatial equilibrium model of the corn market at the state of Chiapas was implemented. Through the model, the consumer and producer surplus were calculated, indicators that measure the benefits of the implementation the agricultural policy.

The spatial equilibrium problem is mathematically expressed as the maximization of the areas under the demand curve minus the areas under the supply curve minus transportation costs. The formulation of the model was based on Takayama and Judge (1971) and on empirical works carried out for crops and agricultural regions of Mexico (García, 2005).

The state of Chiapas was divided into nine corn producing and consuming regions: Centro (made up of 22 municipalities), Altos (18), Fronteriza (9), La Frailesca (5), Norte (23), Selva (14), Sierra (8), Soconusco (16) and Istmo-Costa (3), the model assumes that the supply and demand functions are linear in each region.

Assuming i (i=1,2,3...9) producing regions and j (j=1, 2,3... 9) corn consuming regions, the model is formulated as follows:

$$Max\ VSN = \sum_{j=1}^{J}\left[\lambda_j y_j + \frac{1}{2}\omega_j y_j^2\right] - \sum_{i=1}^{I}\left[v_i x_i + \gamma_i PFE_i x_i + \frac{1}{2}\eta_i x_i^2\right] - \sum_{i=1}^{I}\sum_{j=1}^{J} c_{ij} x_{ij} \qquad (1)$$

where λ_j is the intercept of the demand function for corn in j; y_j is the amount of corn consumed in j; ω_j is the slope of the demand function at j; v_i is the intercept of the supply function at i; x_i is the quantity supplied in region i; γ_j is the parameter of the fertilizer in region i; PFE_i is the price of the fertilizer in region i; η_i: is the slope of the supply function in region i; c_{ij} is the transportation cost of shipping corn from i to j; x_{ij} is the maize shipment from i to j.

The objective function is subject to the following restrictions:

$$\sum_{i=1}^{I} x_{ij} \geq y_j \qquad (2)$$

$$\sum_{j=1}^{J} x_{ij} \leq x_i \qquad (3)$$

$$y_i, x_i, x_{ij} \geq 0 \qquad (4)$$

Equation 2 indicates that the demand in each consuming region i must be less than the corn shipments that come from the producing regions j. Equation 3 indicates that the supply of each producing zone j must be greater than that sent to consuming regions i. Equation 4 indicates the conditions of non-negativity.

To achieve the objectives, two scenarios were evaluated. The first one allowed modeling the situation of the corn market for 2018 when the Fertilizers Program did not exist. The second scenario considers the existence of the program, which implies that the fertilizer used by the producers is provided by the Government.

The intercepts and slopes of the supply and demand functions were estimated using data on their elasticities, production, consumption, and producer prices. Price elasticities of corn supply and demand reported by Espejel (2018), for the southern region of Mexico were used. Production by region was obtained from the SIAP's 2018 agricultural production by crop cycle data.

Regional consumption was estimated by adding the state's consumption in the urban, rural, livestock, and feed processing and cornflour processing industries. Consumption in the urban and rural sectors by the municipality was estimated using data on the *per capita* consumption and population from the National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía, INEGI, 2010; INEGI, 2015). The state livestock consumption by the municipality was estimated using data on the livestock inventory by species (cattle, pigs and poultry) and weights by species; the information came from SIAP (2018a).

Municipal consumption for the feed processing and cornflour processing industry was obtained by weighting the state's consumption for these industries, by each region's share in the value of the state's production; this information for the estimation came from INEGI's economic census (2014).

Transportation costs were calculated using distance matrices (for trucks) connecting the producing and consuming zones. The information on distances was obtained from the Secretary of Communications and Transportation (Secretaría de Comunicaciones y Transportes, SCT, 2020), the unit transportation cost was calculated by adding a fixed factor ($ t^{-1}), plus the product of a variable factor $ (t km)$^{-1}$ by the distance (km) from the producing zones to the consuming zones. The cities taken as reference were the following: Tuxtla Gutierrez (Center), San Cristobal de las Casas (Highlands), Comitán de Dominguez (Border), Villa Flores (Frailesca), Pichucalco (North), Palenque (Jungle), Motozintla (Highlands), Tapachula (Soconusco) and Arriaga (Isthmus-Costa).

The price of the fertilizer was obtained from the National System of Information and Market Integration (Sistema Nacional de Información e Integración de Mercados, SNIIM, 2018), and prices were quoted for each region. Subsequently, a weighted price was calculated to manage an average price across the nine regions.

Both the producer and consumer price were obtained using data from SIAP (2018); the consumer price was estimated by adding the producer price plus the transportation costs of transporting corn from the producing zone *j* to consuming zone *i*.

The solution of the model was obtained using the MINOS procedure written in the GAMS programming language (Murtagh and Saunders, 1998).

RESULTS AND DISCUSSION

Table 2 presents the base year data of the corn market situation, where the fertilizer price is included as an independent variable. Based on the model validation, it is noted that the observed and estimated data are very close. The differences are of less than 5%; therefore, the model can be used for policy scenarios. At the state level, the differences between the observed and estimated values were 0.5% for production and 0.4% for consumption.

In Table 3 the existence of the Fertilizer Program is modeled, that is, the fertilizer price equals zero given the input will be delivered as a subsidy in kind. It is observed that the state production increases by 171 thousand t, which represents a 13% increase compared to the base model in which there is no Fertilizers Program. The usage of chemical fertilizers improves productivity in the field, which allows obtaining greater corn production.

The impact of the Fertilizers Program for the nine regions in the state turns out to be positive; the lower price of the fertilizer shifts the supply curve to the right, causing the production level to increase for each price level. In percentage terms, the greatest effect was observed in the North region, where production increased by 16.1% (13 thousand t), followed by the Soconusco region with 14.7%, Selva and Fronteriza with 13.7% each, Istmo-Costa with 13.5%. Overall, the changes in production with the subsidy ranges from 10 to 16.1%. In absolute terms, the highest growth was observed in Centro where production increased 44 thousand t, compared to the base scenario.

The previous results are similar to those reported by other authors. A study carried out by García-Salazar (2001), found that in the northern regions of the country, where the use of modern technologies that include the use of irrigation, fertilizers, pesticides, and the use of improved seeds predominate, obtain higher productivity of corn compared to that in the south, where traditional technologies are used. This evidence of the importance of the application of fertilizers to increase corn productivity in the southeast, in this case, the state of Chiapas.

The Fertilizers Program was also favorable for consumption. The distribution of fertilizers in kind would increase corn consumption in the entity by 115 thousand t,

Table 2. Validation of the corn model in Chiapas, Mexico in Thousands t.

Region	Consumption observed	Consumption estimated	Change	Change	Production observed	Production estimated	Change	Change
	thousands of t			%	thousands of t			%
Centro	460	455	−5	−1.1	341	348	7	2.1
Altos	123	125	1	1.0	91	91	0	−0.3
Fronteriza	98	100	1	1.3	196	195	−1	−0.6
Frailesca	123	122	0	−0.4	220	223	3	1.5
Norte	140	143	3	2.3	83	82	−1	−1.1
Selva	137	139	3	2.0	231	229	−2	−0.9
Sierra	29	29	0	0.2	54	55	1	1.2
Soconusco	171	173	3	1.5	73	73	0	0.0
Istmo-Costa	80	80	0	0.2	13	13	0	0.9
State total	1,360	1,366	6	0.4	1,303	1,310	7	0.5

Source: author's elaboration with data obtained from the model solution.

Table 3. Effects of the Fertilizers Program on the corn market in Chiapas, Mexico. Thousands of t.

Region	Consumption		Change		Production		Change	
	without FP	with FP			without FP	with FP		
	thousands of t			%	thousands of t			%
Centro	455	499	44	9.6	348	392	44	12.8
Altos	125	135	10	8.0	91	102	12	12.9
Fronteriza	100	107	8	7.9	195	222	27	13.7
Frailesca	122	133	11	9.2	223	247	24	10.7
Norte	143	154	10	7.0	82	95	13	16.1
Selva	139	150	11	7.6	229	261	31	13.7
Sierra	29	31	2	8.4	55	62	7	12.5
Soconusco	173	186	13	7.2	73	84	11	14.7
Istmo-C.	80	86	7	8.4	13	15	2	13.5
State total	1,366	1,481	115	8.4	1,310	1,480	171	13.0

FP=Fertilizers Program.
Source: author's elaboration with data obtained from the model solution.

which represents an increase of 8.4%, compared to that observed in the base model. The region with the highest demand is the center area of the state, in this one, consumption would increase by 44 thousand tons, an increase of 9.6%, compared to the base model. In the rest of the entity's regions, consumption would also increase.

Table 4 presents the results of the scenarios. The producer surplus is the difference between the market price of a given good and their marginal cost of production (Pindyck and Rubinfeld, 2009). Consumer surplus is what the market saves the consumer for what he would be willing to pay (Nicholson, 2006).

The implementation of this Fertilizers Program has positive effects on surpluses for the producer and the consumer. The consumer surplus would increase from 26,479 to 30,822 million pesos, which is an increase of 16.4%, compared to that observed in the base model, in all the corn-producing regions the consumer surplus would increase in a range that goes from 14.5% (observed in the North region of the state) to 19.1% (reposted at La Frailesca).

The producer surplus would increase in all regions of the state, being higher at the Northern region of the state (with 34.8%), in the Soconusco (31.4%) and the Border region (29.4%). The above results are similar to those

Table 4. Effect of the Fertilizers Program on welfare.

Region	Consumer surplus		Change		Producer surplus		Change	
	without FP	with PF			without FP	with FP		
	millions of $			%	millions of $			%
Centro	7,755	9,075	1,320	17.0	5,328	6,776	1,448	27.2
Altos	2,489	2,904	415	16.7	1,655	2,108	453	27.4
Fronteriza	2,018	2,348	330	16.4	3,556	4,601	1,045	29.4
Frailesca	2,122	2,528	406	19.1	3,492	4,279	787	22.5
Norte	3,292	3,768	476	14.5	1,604	2,162	558	34.8
Selva	2,940	3,404	464	15.8	4,164	5,384	1,220	29.3
Sierra	541	636	95	17.6	907	1,149	242	26.7
Soconusco	3,818	4,390	572	15.0	1,371	1,802	431	31.4
Istmo-C.	1,504	1,769	265	17.6	226	291	65	28.8
State	26,479	30,822	4,343	16.4	22,303	28,552	6,249	28.0

FP=Fertilizers Program.
Source: author's elaboration with data obtained from the model solution.

reported by García-Salazar *et al.* (2011) in evaluating the effects of the Program of Direct Support to the Field (Programa de Apoyos Directos al Campo, PROCAMPO) in the corn market in Mexico at the national level; The authors point out that the subsidy granted by PROCAMPO brought with its positive effects on the society's welfare, since the surplus to the producers increased by 10,931 million pesos, compared to that observed in the base model.

In summary, the application of the Fertilizers Program brings positive effects to both, the producers, and the consumers. If both indicators are added, the benefits of the program would increase by more than 10 million pesos. In addition to meeting the objective of the program, which is to contribute to agricultural productivity in localities with a high and very high degree of marginalization, it would also have effects on the consumers.

CONCLUSIONS

This study presents quantitative evidence of the impact and benefits of implementing the Fertilizers Program in the state of Chiapas. The formulation of a spatial equilibrium model of the corn market in the state allowed to determine an increase of 1,480 thousand tons, that would be presented in the production and consumption of corn in 1,481 thousand tons in the state if the Fertilizers Program was applied. The increase in production would allow the state to recover its place as a corn producer in the country.

The positive effects of the Fertilizers Program on producers and consumers surpluses indicate that the benefits for the society at the State of Chiapas would increase by 28,552 and 30,822 million pesos, respectively. Due to the impact and positive effects that the program has on producers and consumers, it is recommended to be extended to all states in the country that have the potential to increase corn production through increased yields.

REFERENCES

Bruce, Murtagh y Michael, S. (1998). MINOS 5.5 User's Guide. En Stanford University Systems Optimization Laboratory.

CEDRSSA. (2019). Notas sobre fertilizantes. Recuperado el 31 de agosto de 2020, de http://www.cedrssa.gob.mx/post_n-fertilizantes-n.htm

Espejel García, M. V. (2018). Impacto de ProAgro sobre la migración y la producción de maíz en México. Tesis de Doctorado. (Colegio de Postgraduados). Recuperado de http://colposdigital.colpos.mx:8080/jspui/handle/10521/2952

García-Salazar, J. A., Skaggs, R., & Crawford, T. L. (2011). PROCAMPO, the Mexican corn market, and Mexican food security. Food Security, 3, 383–394. https://doi.org/10.1007/s12571-011-0138-z

García Salazar, J. A. (2001). Efecto de PROCAMPO sobre la producción y saldo de Comercio Exterior de maiz. Agrociencia, 35(6), 671–683. https://doi.org/1405-3195

García Salazar, J. A. (2005). Modelos de equilibrio espacial e intertemporal. En Notas para Acompañar el Curso. Estado de México: Campus Montecillo.

INEGI (Instituto Nacional de Estadistica y Geografia). (2010). Censo de Población y Vivienda 2010. Recuperado el 8 de mayo de 2020, de http://www.inegi.org.mx/est/contenidos/espanol/metodologias/censos/cpv2010_clasificaciones.pdf

INEGI (Instituto Nacional de Estadística y Geografía). (2014). Censos Económicos 2014. Recuperado el 20 de mayo de 2020, de https://www.inegi.org.mx/app/saic/default.aspx

INEGI (Instituto Nacional de Estadística y Geografía). (2015). Encuesta Intercensal 2015. Recuperado el 9 de mayo de 2020, de World Health Organization website: https://www.inegi.org.mx/programas/intercensal/2015/default.html#Tabulados

Jiménez, N. (2020). Sader presenta programa de fertilizantes; garantiza entrega a tiempo. La Jornada. Recuperado de https://www.jornada.com.mx/ultimas/economia/2020/05/17/sader-presenta-programa-de-fertilizantes-garantiza-entrega-a-tiempo-1178.html

Nicholson, W. (2006). Teoria Microeconomica. Principios básicos y ampliaciones. En Efecto ingreso y efecto sustitución. México. Cengage Learning Editores, S.A. de C.V.

OCDE-FAO. (2019). OCDE-FAO Perspectivas Agrícolas 2019-2028. En OECD Publishing. https://doi.org/https://doi.org/10.1787/7b2e8ba3-es

Pindyck, Robert ; Rubinfeld, D. (2009). Microeconomía. Madrid. PEARSON Prentice Hall. https://doi.org/10.2307/j.ctt2111g56

SADER (Secretaría de Agricultura y Desarrollo Rural). (2019). ¿Qué es y para qué sirve el fertilizante? Recuperado el 25 de mayo de 2020, de https://www.gob.mx/agricultura/articulos/que-es-y-para-que-sirve-el-fertilizante

SCT (Secretaria de comunicaciones y transportes). (2020). Traza tu Ruta. Recuperado el 20 de mayo de 2020, de http://app.sct.gob.mx/sibuac_internet/ControllerUI?action=cmdEscogeRuta

SEGOB (Secretaria de Gobernación). (2019). Plan Nacional de Desarrollo México (2019-2024). Recuperado el 20 de mayo de 2020, de https://www.dof.gob.mx/nota_detalle.php?codigo=5565599&fecha=12/07/2019

SEGOB (Secretaria de Gobernación). (2020). Acuerdo por el que se emiten los Lineamientos de Operación del Programa de fertilizantes para el ejercicio fiscal 2020. 1–13. Recuperado de http://www.dof.gob.mx/nota_detalle.php?codigo=5590178&fecha=24/03/2020

SEGOB (Secretaría de Gobernación). (2019). Acuerdo por el que se emiten los Lineamientos de Operación del Programa de fertilizantes para el ejercicio fiscal 2019.Recuperado de http://dof.gob.mx/nota_detalle.php?codigo=5548785&fecha=24/01/2019

SIAP (Servicio de Información Agroalimentaria y Pesquera). (2013). Boletín semanal del Servicio de Información Agroalimentaria y Pesquera (SIAP) de la SAGARPA. Fertilizantes: alimentos de nuestros alimentos. Recuperado el 31 de agosto de 2020, de http://www.campomexicano.gob.mx/boletinsiap/026-e.html

SIAP (Servicio de Información Agroalimentaria y Pesquera). (2018a). Estadísticas de producción anual ganadera, Anuario estadístico de la producción ganadera. Recuperado el 9 de mayo de 2020, de https://nube.siap.gob.mx/cierre_pecuario/

SIAP (Servicio de Información Agroalimentaria y Pesquera). (2018b). Producción Anual, Cierre de la Producción Agrícola por Cultivo. Recuperado el 8 de mayo de 2020, de https://nube.siap.gob.mx/cierreagricola/

SNIIM (Sistema Nacional de Información e Integracíon de Mercados). (2018). Insumos Agricolas. Recuperado el 23 de mayo de 2020, de http://www.economia-sniim.gob.mx/nuevo/Home.aspx?opcion=Consultas/MercadosNacionales/PreciosDeMercado/Agricolas/ConsultaInsumos.aspx?SubOpcion=9%7C0

Takayama, T., and G. G. J. (1971). Spatial and Temporal Price and Allocation Models. North-Holland Publishing, Company. Amsterdam, Holland.

AP AGRO PRODUCTIVIDAD

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Characterization of producers of Ejido San Luis Huexotla and relationship with socioeconomic structure and agricultural production

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ABSTRACT

Objective: To characterize the Ejido agricultural producers relating to their environment and socioeconomic structure in Ejido San Luis Huexotla, Texcoco, state of México, Mexico.

Design/Methodology/Approach: This research joined qualitative and quantitative methodologies. Also, a survey was used and applied to Ejido producers (ejidatarios) of Ejido San Luis Huexotla. To obtain the sample size, total universe of 181 ejidatarios was used; and survey was applied to 50 of them, representing 30% of the population.

Results: The main problems were identified that have changed land uses and ownership in the Ejido. Variables were found, as aging and primary economic activities that are decisive in order to know the current status of the Ejido area; its spatial transformation, and general conditions of Ejido San Luis Huexotla.

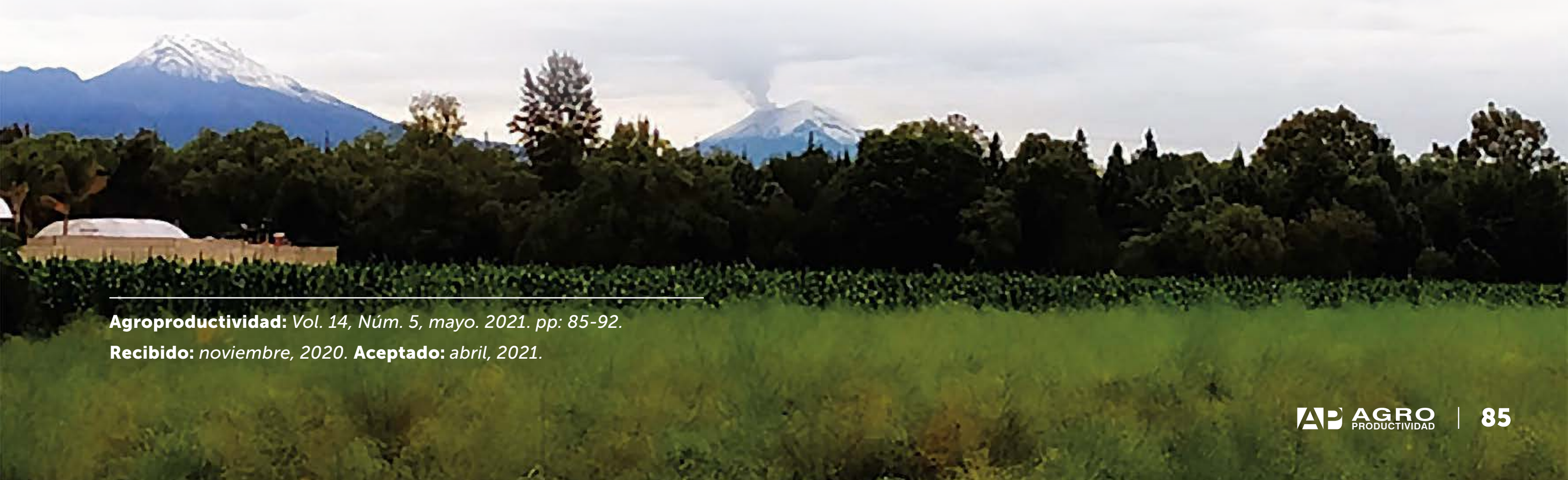
Limitations of the study: Although we are referring to an agricultural area with irrigation systems, diverse causes and socioeconomic factors or even external factors have conditioned the agricultural activity of the Ejido system.

Findings/Conclusions: Applying a survey to ejidatarios was decisive to observe the conditions in which the Ejido is being managed; and to assess vulnerability to external events that have transformed the actions at the Ejido; as well as their socioeconomic relationships facing the inevitable de-peasant process (less owners are rural farmers by the day) in current Mexican agricultural lands.

Key words: agricultural producers, Ejido San Luis Huexotla, socio-economic structure.

INTRODUCTION

The Ejido has played an important role within Mexican agriculture as foundation for family agricultural production. However, it has had also the main role in significant changes in terms of land tenure, following 1992 reforms to the Article 27 in the Mexican Constitution Act. This reform modified not only the action of the Ejido, but its social practices and current status.



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The Ejido de San Luis Huexotla has a historical precedent of endowment that places it within the extensive process of the agrarian distribution in 1927 (Espinosa, 2017). The Ejido zone which was granted on March 3, 1927 by Presidential decree with a total of 237 ha, of which 108 ha are wetlands; 16 ha are rain fed; and 113 ha are pasture and pond. The environment and its geographical location were crucial for, since 2008, the Federal Government made land purchase of Ejido and communal lands, totaling 1700 hectares in the municipalities of Texcoco and Atenco. These lands belonged to seven ejidos (Santa Isabel Ixtapan, San Luis Huexotla, Hidalgo y Carrizo, San Bernardino, San Cristóbal Nexquipayac, Francisco I. Madero, San Felipe and Santa Cruz). Such a purchase intended to form a rural polygon of soils for the ecological rescue of the whole zone, according to the "Mandatory Book of CONAGUA-07, Lake Texcoco Ecological Program" (CONAGUA, 2012). However, in real terms, that purchase was for what would eventually be the Mexico City New International Airport (NAIM, in Spanish); the first process that drastically changed the dynamics of the Ejido San Luis Huexotla.

In Mexico, land tenure is a fundamental part of the structure of our territories; not only in a political, social, or economic way, but also as a functional structure. Bearing in mind that Ejidos and agrarian communities are the main reference for the geographic occupation of our National territory. And that they occupy 102 million ha (84.5 million, ejidos and 17.4 million, communities), equivalent to 53.4% of Mexico National surface (Morett, 2017). The 1992 Agrarian Law stated that a Ejido is constituted by the endowment of Ejido lands which, according to their destination are: human settlements; lands of common use parceled out to farmers, managed by a common property association with a decision-making entity – the representative assembly (commissariat) and the control assembly (supervisory council). According to the Agrarian Procurator Office (2009) Ejido is defined as the "population settlement, made up of all the lands, forests, and waters of an endowment, as well as the group of individuals holding those agrarian rights".

This study shows the characterization of ejidatarios regarding their socioeconomic characteristics (age, level of education, social security, possession of land) and their agricultural activity, in order to know their activity status and type of production. All this aiming to have a general scope of the conditions of ejidatarios in Ejido San Luis Huexotla; in addition to identifying those external factors that have modified their actions in the Ejido.

MATERIALS AND METHODS

This research was carried out in the town of San Luis Huexotla, which is located within the Municipality of Texcoco to the east of the state of Mexico. The municipality is made up of a Municipal District, which is Texcoco de Mora city, divided into 19 territorial units (neighborhoods, colonies, and private subdivisions). And other 60 localities are considered under Texcoco Municipality, that are grouped in 6 zones for their territorial administration management (H. Ayuntamiento, 2016).

San Luis Huexotla (town) has an Ejido zone located on the lake shore of Texcoco, bordering to the north with Col. Nezahualcóyotl; to the south with San Bernardino; to the east with lands of Universidad Autónoma Chapingo (UACH); and to the west with Ejido San Martín. San Luis Huexotla Ejido is divided into the zones: 1st and 2nd tables of San Andrés; El Colorado; and Santa Irene.

Methodology. The study population was selected with the aim of redefining and making accurate the list of ejidatarios, considering the reduction of members due to the sale of the Ejido Huexotla carried out in 2010. After this sale there remained only 181 ejidatarios in Ejido's updated list, although The National Agrarian Registry (in Spanish, RAN) has 237 registered. It was decided to apply the survey to those who still have a plot in the Ejido to obtain data on the type of agriculture they carry out, and to discard those members who sold to CONAGUA in 2010.

To obtain the selection of the sample, a non-probabilistic sampling was considered, because we did not have the official registry list of ejidatarios. The snowball method was used, some ejidatarios were located and they brought in more people to the survey until the sample size of the population was completed. To obtain the appropriate sample size, the universe of 181 ejidatarios was used, and 50 surveys were applied for sampling about 30% of the total population.

The statistical analysis was carried out in the statistical system SSPS (Statistical Package for the Social Sciences) in addition we used Microsoft Excel to draw the graphs.

RESULTS AND DISCUSSION

Results obtained through the survey show that 50 ejidatarios of Ejido Huexotla, provided socioeconomic information that helped us to characterize their personal information. From there, also to know the factors that have determined the land use of their plot possession, and their relationship with it.

Age and Sex. From the analysis of the data obtained we observe that the average age of male ejidatarios is 61 years, and 72 years of women; 88% are males and only 6% are females. The number of women is minimum compared to men, and this is logical, considering that for the endowment of Ejido lands in the Mexican agrarian distribution, only men were considered. However, this low percentage of female representation is due to the succession of Ejido rights (Table 1).

The successions because of appeal on the grounds of constitutionality rights (in Spanish, amparo) in agrarian matters are regulated by the Agrarian Law (1992), in Article 17 that mentions the power that the ejidatario has when designating who should succeed him in his rights respect to the plot, and the order of preference in relation to the award of rights upon death. Art. 18 indicates that when the ejidatario did not designate the successor, the agrarian rights are transferred according to the following order: I) Spouse II) Concubine or common-law partner, III) son of ejidatario, IV) one of his ascendants, V) any person who depends economically on him. Article 19 establishes that when there are no successors, the Agrarian Court will sell the rights to the highest bidder among the ejidatarios and avecindados (other people resident in the Ejido).

SAGARPA (2014) mentions that "the majority presence of farmers in old age has implications for the production, handling, and management of natural resources in agriculture". Thus, it is important to mention that the age ranges shown in the following graph depict the condition of field activity at Ejido Huexotla. The aging of the population is a factor regarding production capacity, due to the decrease in physical abilities. The study population shows that 52% of the producers are over 61 years, this means they are elders; while 44% are between 40 and 60 years of age (Graph 1).

The decrease in young people in the agricultural sector shows their low participation in the Ejido Huexotla.

Table 1. Distribution by gender and average age.

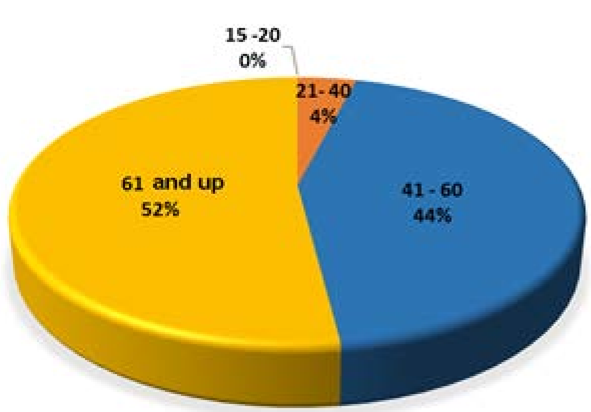
Sex	Frequency	%	Average Age
Man	44	88	61
Woman	6	12	72
Total	50	100	66.5

Only 4% are between 21 and 40 years of age, which represents the abandonment of agriculture, and a possible reorientation of their economic activities.

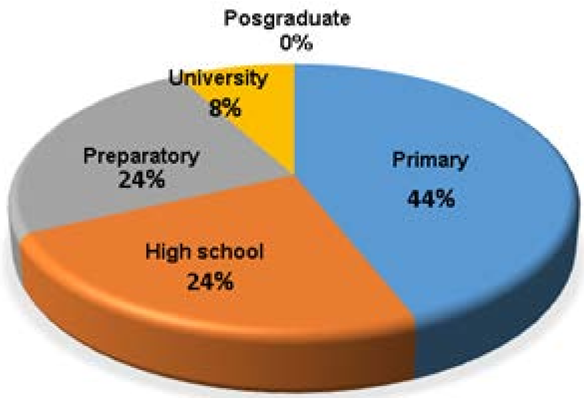
Education level. According to the results of INEGI (2010), the Municipality of Texcoco has a population of 167,309 people (15 years or older). Of which 5,295 are illiterate; 13,859 people without complete elementary school; and 31,395 without complete secondary (junior high) school. For a total of 50, 549 people lagging behind in education.

From results obtained in the survey, we found that 44% of ejidatarios studied elementary school, of them, only 10 studied from 2nd to 5th grade of elementary school and all the rest finished it. In addition, 24% studied secondary school. Following these results that show a low academic level in the respondents, illiteracy is identified as a problem, affecting at National level, but especially in the primary production sector. The most lagging behind people regarding education are those who are dedicated to agriculture and other related field activities (Graph 2).

Social security. It shows a comprehensive stability regarding guaranteed health care and medical services, according to IGECEM (2016). Public health system and social security, along with private and social assistance institutions in Texcoco, report a total population of 240,



Graph 1. Age of the Huexotla Ejido stakeholders.



Graph 2. Education level of the respondents.

749 people. Of which 181,785 people are beneficiaries of a social security public institution, and 57,607 do not have any social security scheme.

The medical assistance services are shown in the following table, 62% people have ISSSTE as their medical service. We should clarify that this service is provided to workers, former workers, family members, and pensioners of the Federal Government and the Federate states. This means that those ejidatarios who have the service, do it because they also work or worked in a government agency. Due to the characteristics of the area, most did in Universidad Autónoma Chapingo (UACh) and Colegio de Postgraduados (COLPOS); while the other 26% are not affiliated with any medical service, which means that they eventually pay private service (Table 2).

Socio-economic structure. The economic composition is a fundamental piece of information about land owners, their employment, and income from agricultural activities. Because it shows or estimate the economic stability of the ejidatarios' families. In this area of the primary production sector, we can consider that very high risks are run by the abandonment of agricultural and livestock activities; due to the almost zero obtaining of agricultural products for self-consumption, the scarcity of government support, and the change of land use constantly oriented towards urbanization, that put agriculture at an exponential rate risk. Therefore, it is necessary to know the current condition of Ejido Huexotla.

Table 2. Social security of ejidatarios in Ejido San Luis Huexotla.

Medical Services	Frequency	%
ISSSTE	31	62
IMSS	2	4
ISSEMYM	0	0
SSA	0	0
SEGURO POPULAR	4	8
NINGUNO	13	26
Total	50	100

The economic inputs in the agricultural sector of the region may frame the possibility of continuing to carry out these activities or abandoning it due to the aforementioned factors. It is necessary to indicate that the challenges that the municipal governments must face should be aimed at improving public policies to activate local production; and to stop urbanistic growth that continues to be a prevailing risk factor in spaces originally used for agriculture.

San Luis Huexotla ejidatarios have plots of approximately 1 ha, in some cases it varies because they have between 9000 m^2 and 10,000 m^2, although the majority possess 1 ha of the Ejido land per ejidatario.

Economic income from other activities. It is important to know those economic activities that are not agricultural because those are for some people, sources of main income; henceforth, the dependence degree of agricultural production to them. In this section we get to know this type of additional activities.

In Ejido Huexotla, most ejidatarios alternate their agricultural works with other economic activities that generate the main economic support of their family. It is worth mentioning that the economic income from agriculture is not enough to cover their expenses. Hence the need to have an extra source of income intending to guarantee their financial security (Table 3).

Table 3. Other economic activities of ejidatarios.

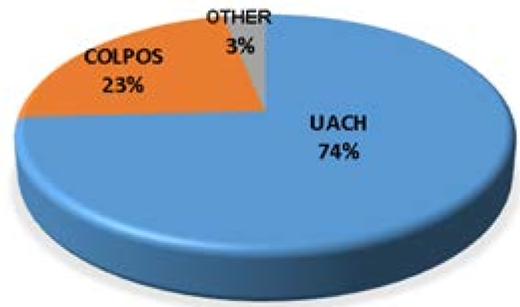
Economic activity	Frequency	%
Government employee	12	24
Retired	20	40
Private company employee	0	0
Technical professional	2	4
Businessman	5	10
Laborer	6	12
Tailor	0	0
Other	5	10
Sum	50	100

The economic support of families is a priority in the whole of society, it is part of the responsibility that one must secure family well-being. At the previous table we observe that 40% of those surveyed are retired people from some government agency. This means that at present they receive a pension for their years of service, while 24% work in a government institution, and they report economic security, in addition to some day they will be pensioners. We should clarify that 10% who answered "Another type of activity" are women who got the retirement rights by their deceased husband. Other 4% have a professional degree and they can get salary for their services. If we add these items, they mean that 78% of the total interviewees reported to have economic stability (Graph 3).

In general, people who mentioned working or being retired by a government agency have the possibility of guaranteeing economic stability.

The role that these institutions play in the area is fundamental for economic and academic development, not only for the Municipality of Texcoco but also on the National level. Regarding academic sector UACH is a public institution that provides education from Senior High School level, College and Postgraduate degrees. It is dedicated to teaching and research in agronomic and environmental sciences. On the other hand, COLPOS provides Postgraduate education, conducting international research, and providing services and technical assistance in agriculture, and forestry. Both institutions have a large staff of students, which means that the localities around them demand spaces for housing and services, which generates additional economic incomes in the area.

Also, these institutions as employment source generated a local economic dynamic, by providing administrative workspaces, mainly occupied by people of the municipality. The search for new spaces to access a stable economy was the main reason for people to apply to these institutions. There is this guarantee by being government institutions that provide job security, services, benefits that effectively privilege their members. But, on the other hand, this was also the main factor for people, who at some points were engaged in agriculture, abandoned little by little those agricultural activities.



Graph 3. Government institutions in which S.L. Huexotla ejidatarios work

Type of possession to the ejido. To acquire the title of ejidatario according to Art. 15 of the 1992 Agrarian Law is required. "To be Mexican of legal age, or of any age if he has a family in his charge or is an ejido heir"; "being a resident of the corresponding ejido, except in the case of an heir; or comply with the requirements established by each ejido in its internal regulations." And it is accredited if he has the certificate of agrarian rights and the parcel certificate.

The following table shows what has been the way in which they acquired their Ejido plots, the agrarian subjects mentioned that 72% have possession by inheritance. That is, they were designated as successors so that ejidal rights are accredited and therefore the accreditation as ejidatario. Other 12% mentioned having acquired their plot at Ejido by direct purchase; 10% indicated that by "other type of acquisition" which refers to the fact that on the death of the owner there was no succession designation, and the rights were assigned in order of preference to the succession list according to the adjudication of rights to his death mentioned in Art. 17 and 18 of the Agrarian Law (Table 4).

Table 4. Form of acquisition in which the Ejido plot was acquired.

Way of acquiring	Frequency	%
Purchase	6	12
Inheritance	36	72
Irregular Possession	2	4
Agrarian cast	1	2
Other	5	10
Total	50	100

Public services in the ejido. One characteristic that should be mentioned is that the Ejido has water wells for irrigation (Santa Irene, San Andrés, Gama). The latter was sold when the purchase was made by CONAGUA in 2010; they also have the use of wastewater since 1975 from the Chapingo river. This court sentence was pronounced in the Agrarian Trial number 707/92, relative to the provision of water, promoted by peasants from the town of San Luis Huexotla. Such a request was made since 1979 and granted with an endowment of 414,720 m^3 (four hundred fourteen thousand seven hundred and twenty cubic meters) of water, and waterflow of 20 L/s during the 8 months of seasonal drought (DOF, 1994).

Table 5. Public property services.

Public Services	Ejido	
	Yes	No
Water	2%	98%
Sewer system	0%	100%
Electricity	6%	94%
Telephone	2%	98%
Pavement	0%	100%

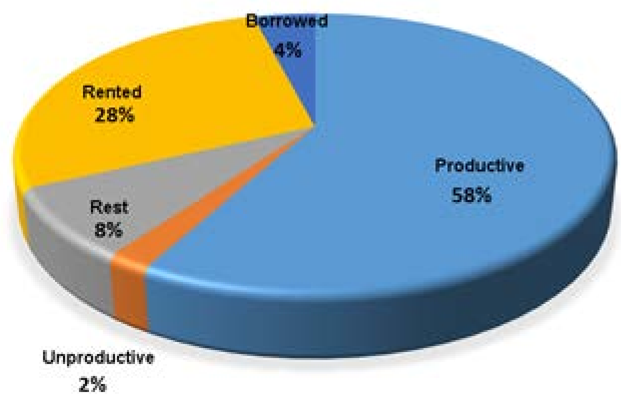
There is little coverage of public services regarding the Ejido zone, in the following table we see what percentage of services the ejidal properties have. For example, 98% of the Ejido plots do not have piped water service; thus, the dwellings settled in these spaces have to buy tap water volumes (in water tanker trucks) for domestic use (Table 5).

Natural state of the plots. The type of agriculture carried out by the ejidatarios is a traditional type. They continue to plant basic products such as corn, and their agricultural exploitation depends on personal needs. Although some prefer not to plant it for different reasons. In the following graph we can see the current state in which the lands of the Ejido are. A 58% of the plots are producing, while 28% the ejidatarios prefer to rent their land. The latter refers to owners who prefer to obtain a secure profit annually. The price of the annual rent varies according to what is agreed among those involved; from 3,000 to 5,000 thousand pesos (Graph 4).

Type of crops. The main agricultural products that are sown in the Ejido are maize grain with 45%, and oats with 30%. One of the respondents mentioned planting asparagus; this product is one of the least considered in the Ejido, but with great potential. Although the market is scarce, the economic retribution is higher compared to the basic products planted in the area. It is worth mentioning that this product demands intense care, but the climatic conditions favor its production (Figure 1).

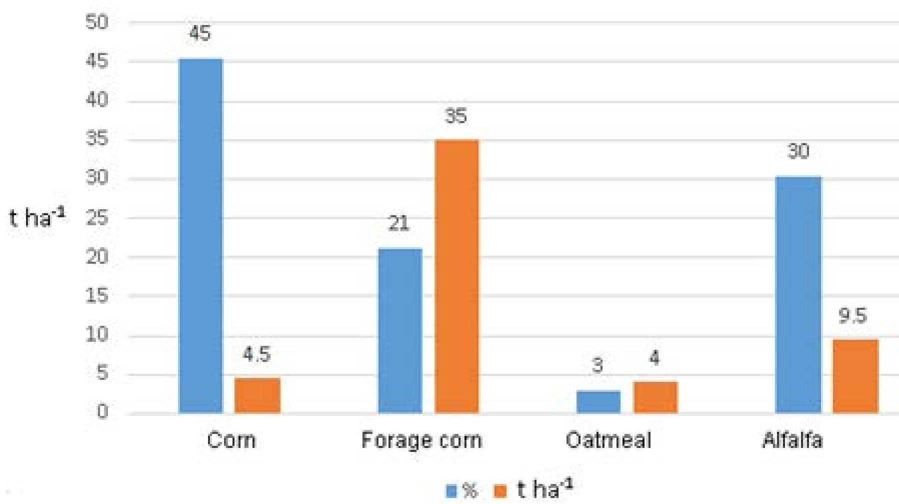
The yields depend on the type of crop; in the case of maize grain it ranges from 4 to 5 tons/ha; and the estimated price of 4000 thousand pesos per ton. While forage corn has a variation of 3,500 to 4,000 thousand pesos ton/ha. Although there is the introduction of improved seeds and fertilizers, some ejidatarios resort to purchasing from the Secretaría de Desarrollo Agropecuario (SEDAGRO) (Graph 5).

The destination given to agricultural products depends on the need of the producer: 45% who sow maize grain



Graph 4. Current status of the Ejido lands.

Figure 1. The Asparagus plot.



Graph 5. Type of crops in Ejido San Luis Huexotla.

activities in this area. There remains as in alert, the possibility of drastic changes in land use in this area; because surveyed ejidatarios mentioned their willingness to sell if there is a customer with possibility of purchasing. Although they are surrounded by the main agricultural researchers at Mexico's National level, such as UACH, COLPOS and INIFAP, ejidatarios do not approach to them to request information, nor advice to increase their yields and improve production.

mentioned using it for self-consumption. That is, family food and their animals. Whereas 8 respondents sow maize with the goal of selling their entire production.

Government Supports. Governmental Funds supporting farms is an important factor for the ejidatarios. However only 12 people of the respondents mentioned having any type of support; 8 of them receive the PROCAMPO (Programa de Apoyos Directos para el Campo or support funds directly to the farm) for the amount of $1,300 MXN pesos (65 USD) from SAGARPA since 1993. This so-called support is a mechanism for transferring resources to compensate domestic producers by those subsidies that their foreign competitors receive. As replacing the scheme of guaranteed prices for grains and oilseeds (SAGARPA, 2012) (Table 6).

CONCLUSIONS

The first territorial change that the San Luis Huexotla ejido suffered was the sale of 37.81 ha of the original (53.43 ha) common use area in the Ejido surface. Lands that were sold to CONAGUA in 2010. This meant that 56 ejidatarios sold their plots, leaving the Ejido reduced to a total area of 146 ha. The sale had direct effects on the agricultural production which the irrigated agriculture area used to produce; also, the disappearance of the common use lands at the Ejido.

On the contrary, parceled land price increased because of capital gain, in relation to agricultural land price, due to demand of surface for the constructions associated with the establishment of the NAICM (Mexico City New International Airport). All this presents a risk to the entire ejidal zone and generated the decrease of agricultural

Although it is true that agricultural land in the Ejido zone up to 2016 decreased due to the sale to CONAGUA, we also observed that there is an agricultural decrease in the whole area. Results show disinterest in carrying out agricultural activities. We found just 58% of the plots are producing, while the remaining 42% of people do not work lands directly. Therefore, this leads to think that agriculture for the ejidatarios does not represent a profitable economic activity; fact that is expressed through a lot of lands in rest, without agricultural activity. Associated with this trend, the survey found that 74% of the ejidatarios work or have worked in a government agency like COLPOS or UACH. Most frequently, this shows that, associated with the aforementioned decrement problems on the agricultural production, the abandonment process is also related to obtaining a stable source of income. All this leads to leaving agricultural activities as second and even third economic option.

On the other hand, the agricultural structure has also generated a change in land uses in the Ejido zone. Thus leading to modifying production processes; causing rent of their lands, abandoning them or even selling in some cases. Ejidatarios informed that 58% of them cultivate

Table 6. Type of Government Support Funds for Farming.

Program	Number of supports	Type of support
Procampo	8	1300 pesos
Alliance for the field	2	Fertilizer
Livestock Program	1	3750 per 10 head of cattle
Strategic Food Security Project (PESA)	1	Technical Advisory

their lands; 28% rent them; 8% leave them on rest; and 4% give them on loan. Of the percentage that actually cultivate lands, those products obtained are destined, 55% for self-consumption and 45% for sale.

Finally, a factor that has also influenced the low production of the agricultural area has to do with the elder age of the ejidatarios. Aging is one of the main factors limiting agricultural production, regarding primary human capital (FAO, 2014; SAGARPA, 2014).

REFERENCES

CONAGUA (2012). Comisión Nacional del Agua, Libro Blanco Conagua-07 "Programa Ecológico Lago de Texcoco". Gobierno Federal.

Diario Oficial de la Federación (1994). Dotación de agua, Sentencia pronunciada en el juicio agrario número 707/92.

Espinosa Morales J.C. 2017. Cambio de ocupación del suelo en la localidad de San Luis Huexotla Texcoco Estado de México en el período 1996-2016: Tesis de Maestría en Ciencias. Colegio de Postgraduados, México.

IGESEM (2016) Instituto de información e Investigación geográfica, estadística y catastral del Estado de México. "Estadística básica municipal"

INEGI, (2010). Censos Generales de Población y Vivienda.

FAO (2014). Organización de las Naciones Unidas para la Alimentación y la Agricultura. "Estudio sobre el envejecimiento de la población rural en México.

H. Ayuntamiento Texcoco (2016). Bando de Gobierno del Municipio de Texcoco.

Ley Agraria (1992). Cámara de Diputados del Congreso de la Unión. Últimas Reformas DOF25-06-2018

Morett-Sánchez, J. Carlos, & Cosío-Ruiz, Celsa. (2017). Panorama de los ejidos y comunidades agrarias en México. Agricultura, sociedad y desarrollo, 14(1), 125-152. Recuperado en 13 de octubre de 2020, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1870-54722017000100125&lng=es&tlng=es.

Procuraduría Agraria (2009), Glosario de términos jurídico-agrarios,

Ruiz Alarcón, A. (2014). La organización ejidal en el desarrollo rural de México. Estudios Agrarios. 2015, 59, 181–204 204.

SAGARPA (2012). Programa de Apoyos Directos al Campo (PROCAMPO). Reglas de operación.

SAGARPA, (2014). Estudio sobre el envejecimiento de la población rural en México.

https://doi.org/10.32854/agrop.v14i05.1866

Technological gap in allspice (*Pimenta dioica* L. Merr) production

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ABSTRACT

Objective: To study the technological features of allspice (Pimenta dioica L. Merr) production and to show potential areas of social intervention in the crop.

Methodology: The study took place in five of 22 producing municipalities in Veracruz state, Mexico, selected by non-probabilistic sampling; n = 50 surveys were applied to producers selected following the snowball method. Data were collected on profile of the production unit and knowledge-practice for innovations. Descriptive statistics were applied; knowledge-practice rates and knowledge-practice indices were calculated. A classification of areas of opportunity was made based on the diffusion of innovations theory.

Results: Allspice occupies small areas, its a complementary crop; knowledge and practice rates show that the categories for marketing, organization and nutrition are the lowest; in the opposite direction are the categories for harvesting, sustainable management and agronomic management. The categories show areas of opportunity for intervention, for the less known and practiced innovations; as well as opportunity for reinvention of known and practiced categories.

Study limitations: Due to difficult access to producer databases, it was decided to conduct a snowball sampling method.

Conclusions: The increase in knowledge and practice rates are determined by the areas of opportunity and the restructuring of the known innovations. The role played by allspice, the occupied surface and the presence of other commercial crops can explain the state of production.

Key words: Innovation, Knowledge index, Practice index, Production.

INTRODUCTION

Spices have accompanied the development of mankind since ancient times; these were reason for conquests and expansion to new territories (Claridades Agropecuarias, 2001; Morales, 2008; Rao *et al*., 2012). Records suggest that there are 26 thousand species of edible plants with different applications, including all peppers (Morales, 2008). The allspice (*Pimenta dioica* L. Merr) (Myrtaceae) is a spice native to Mesoamerica, adapted and cultivated in various areas of the world (CONABIO, 1947; Gómez, 2007; Jaramillo, 2014; Reyes-Martínez, 2017).

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Several studies record that allspice has been used in the food industry, cosmetics and perfumery (Macia Barco, 1998; Monroy Rivera, 2011; Rao *et al*., 2012). Other research report that different active ingredients extracted from allspice present anticancer, antifungal, antimicrobial, nematicide, antioxidant, antidiabetic and anti-inflammatory activity, which is used by the pharmaceutical industry (Lim, 2012; Rema & Krishnamoordthy, 2012; Sol-Sánchez *et al*., 2018; Zhang & L. Lokeshwar, 2012).

In Mexico, in order of importance, allspice production is concentrated in the states of Veracruz, Tabasco, Chiapas and Puebla (Jaramillo, 2014; Martínez-Pérez et al., 2013). According to Gómez (2007); Jaramillo (2014) and Martínez-Pérez *et al*. (2013) most of this production comes from plots where allspice is grown as a complement to a main activity, with little agronomic management and dispersed in pastures.

Martínez-Pérez *et al*. (2013) reported that through innovation management agencies, the adoption of the allspice technological package was promoted as part of the Humid Tropics Program, resulting in a low integration of new forms of production and organization by producers, especially in the state of Veracruz. In the same way, little interest has been documented on the producers to carry out agronomic practices on this crop (Martínez-Pérez *et al*. 2013; Reyes-Martínez, 2017).

An accelerated adoption of innovations, according to Ullah *et al*. (2020), results in a positive growth in agricultural productivity, sustainable agricultural land use and an overall path to food security. To expand practice in agriculture, Zainal and Hamzah (2018) stated that the improvement of farmers' knowledge is required; also, Odame *et al*. (2020) stated that, knowledge specific to each area and that provided by science should be integrated; in this way a holistic approach to the practices proposed to farmers can be achieved. Based on the above, the technological aspects in the production of allspice were studied to show potential areas of social intervention for this crop.

MATERIALS AND METHODS

The research took place in five of 22 allspice-producing municipalities at Veracruz, Mexico (Altotonga, Atzalan, Catemaco, Misantla and Tlapacoyan). These were selected by non-probabilistic sampling directed to convenience based on the production records by municipality of the SIAP (2018). During June and July 2019, n=50 producers of allspice sampled by the snowball method were interviewed.

A survey of 24 questions and a catalog of 28 innovation practices were designed, divided into the categories for: nutrition, plant health, sustainable resource management and establishment of the plantation, administration, marketing, organization, harvest and postharvest; and agronomic management; which was adapted from the UTE-Innovation proposal (2013). In the survey, data was collected on the profile of the production unit, as well as the knowledge and implementation of innovation practices in its production units (Table 1).

The information collected from the surveys was captured in a mask designed for that purpose; the data of the producer's profile and the production unit were processed to obtain descriptive statistics. The information from the innovation practices catalog was captured and coded to obtain: the knowledge rates and practice rates by category; as well as the knowledge index and the innovation practice index.

The knowledge index (KIn) and the practice index (PIn) were constructed following the methodology proposed by Muñoz-Rodríguez *et al*. (2007) of the innovation adoption index IAIn. The KIn and PIn consist of mapping what the producers knows and what they know and does.

The way to compare between the indices for its interpretation is to make it similar to the IAIn in the following way: the baseline is pared to the knowledge index and the final line is pared of the practice index. The difference between the baseline and the final line gives the gap of the increase or decrease in time, in the case of the difference between KIn and PIn we obtain the gap of what is known is being applied. While the timeline that clearly distinguishes IAIn is not examined, the existing gap between KIn and PIn can help to clarify what actions to take in addressing areas of opportunity for allspice production.

The areas of opportunity were determined as a basis in the theory of innovations diffusion proposed by Rogers (1995), where five categories to classify the units that adopt innovations were defined. The first two categories (Innovators [2.5 %], early adopters [13.5 %]) were taken as the areas with the greatest opportunity for intervention,

Table 1. Innovations catalogue.

Category	Innovation
A. Nutrition	A1. Analysis for the determination of fertilization dose
	A2. Soil amendment techniques: lime, sulfur, manure
	A3. Macroelements: Nitrogen, phosphorus, potassium, calcium, magnesium and sulfur
	A4. Microelements: Zinc, manganese, boron, iron and copper
B. Plant Health	B5. Pest and disease monitoring
	B6. Sanitary pruning
	B7. Formation pruning
	B8. Control of pests and diseases
C. Sustainable resource management and plantation establishment	C9. Organic fertilizers, compost and vermicompost
	C10. Crops with which allspice can be associated
	C11. Plantation establishment specifications based on specific requirements or technological package for allspice (density, agroclimatic, edaphological, etc.)
D. Administration	D12. Scheduling of activities / processes
	D13. Register the practices carried out in the cultivation (date, inputs, practice)
	D14. Register the quantity and quality of the harvested fruit
E. Commercialization	E15. Register the income and expenses of the production unit
	E16. Consolidated purchases
	E17. Consolidated sales
F. Organization	F18. Advisory services, financial services
	F19. Plantation management activities
	F20. Allspice Producers Organization
G. Harvest and postharvest	G21. Scheduling for the collection and sale of allspice
	G22. Tools that facilitate harvesting (tall limb pruner, scissors, chain saws)
	G23. Sale of fresh allspice
	G24. Sun drying process
	G25. Drying process with machines
H. Agronomic management	H26. Plants of varieties improved or validated varieties in the production unit
	H27. Own plants with better yields and resistance to diseases
	H28. Grafted allspice plants

Source: Adapted in 2019, based on the approach UTE-Innovación (2013).

the third category (earlyest [34%]) as those requiring reinforcement, and finally the fourth and fifth categories (latest [34%] and laggards [16%]) where interventions are no longer necessary and possibly present an area of opportunity to rethink these innovations.

RESULTS AND DISCUSSION

The general profile of allspice production shows that their production units mainly cultivate bananas, coffee, corn, lemon, and other crops. In some cases, cattle are raised; allspice occupies a role different from the main crop in 96% of the cases. The results show that for producers who have diversified production systems, with more than two crops, allspice occupies an average of 39% of the surface, and for producers who have diversified production systems with just two crops, allspice represents on average 71% of the area sown.

The mapping of the innovation catalog showed the level of knowledge and practice by category; the lowest knowledge rates were marketing (19%), organization (19%) and administration (37%); with the exception of the administration category, these categories also had low practice rates, 6% and 5% respectively, adding to this list the nutrition category (10%). The categories with the highest knowledge rates were harvest (77%), sustainable management and plantation establishment

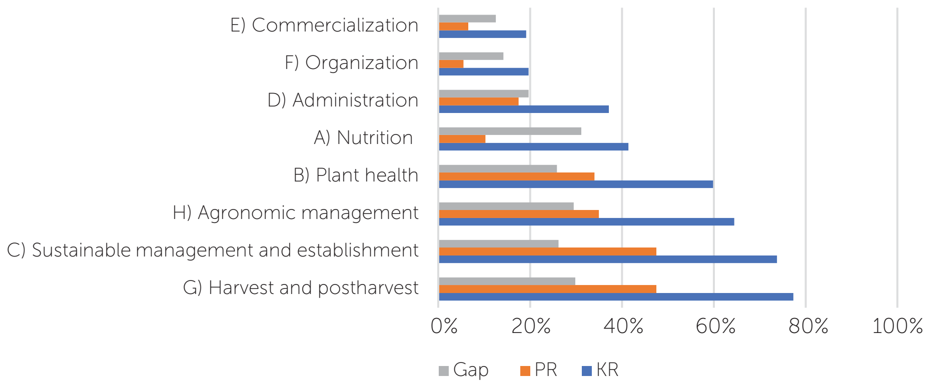

Figure 1. Knowledge (KR) and practice (PR) rates by category (2020).

(73%), and agronomic management (64%); These categories had also the largest practical knowledge gaps, therefore added to category A). Nutrition (Figure 1).

Figure 2 shows the knowledge index and the practice index of the innovations that comprise each category; in category E) marketing, the least known variables were the consolidated purchases and sales; in category F) organization, the least known activities were the contracting of consulting and financial services, as well as group management of the plantation; in category D) administration, the least known information were the recording of practices carried out on the crops, as well as the recording of the quality and quantity of the harvested fruits.

The best-known innovations present the largest gaps; in category A) for nutrition these are: soil amendment techniques and the application of microelements; in category H) agronomic management, these were the selection of plants with better yields and resistance, as well as the usage of grafted plants; the last in this classification is category G) harvesting, where the least practiced innovations were the sun-drying process and machines drying.

Areas of opportunity

Important areas of intervention are found in innovations the A1, analysis for determining fertilization doses, A4 microelements, D14 recording the quantity and quality of harvested fruit, E16 consolidated purchases, E17 consolidated sales, F18 advisory services and financial services, F19 group management of the plantations, and F20, organization of allspice producers. Given that

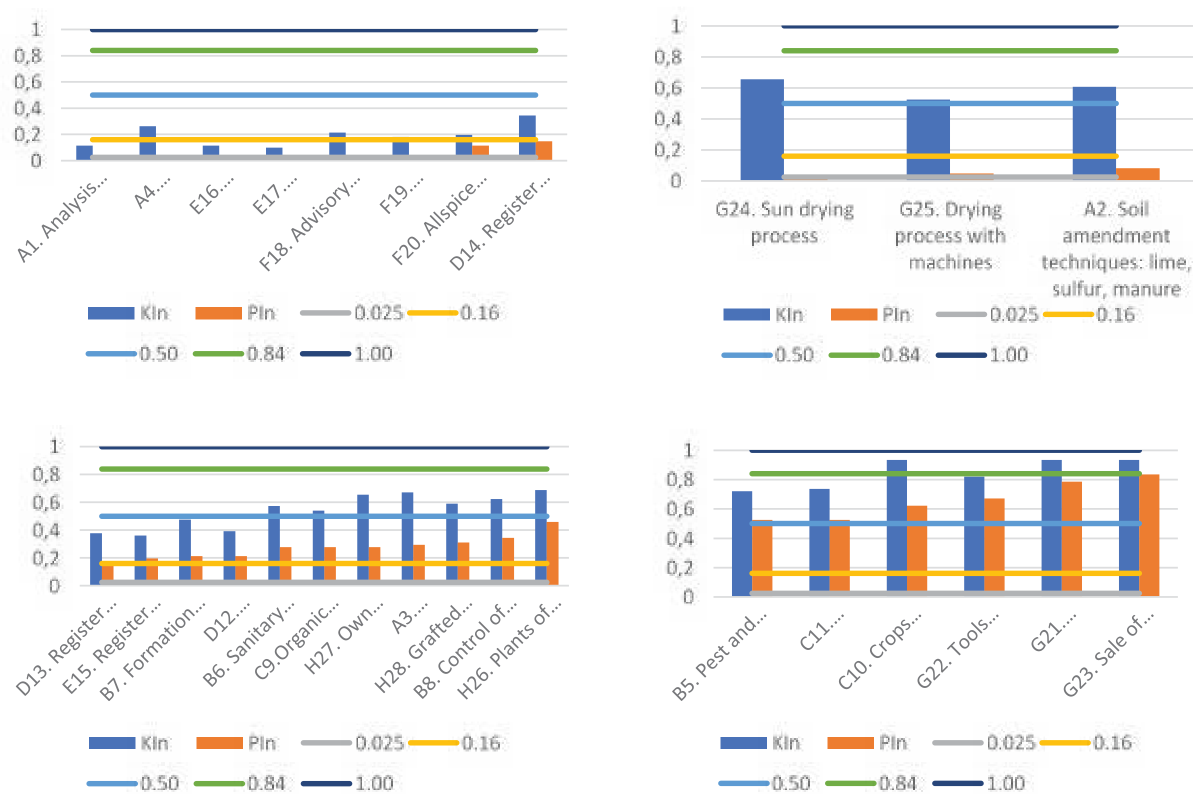

Figure 2. Knowledge Index (KIn) and Practice Index (PIn) by Opportunity Areas (2020).

these are the least known and practiced, they provide an opportunity to insert this knowledge into the producers' production systems.

The innovations that presented a lower than 0.50 index in the practice were: A3 macroelements, B6 sanitary pruning, B7 formation pruning, B8 pest and disease control, C9 application of organic fertilizers, compost and vermicompost, D12 calendarization of their activities/processes, D13 recording of the practices carried out in the crops, E15 recording of income and the expenditure of the production units, H26 improved or validated varieties in the production unit, H27 own plants with better yields and diseases resistance and H28 grafted allspice plants; these innovations already flow among the activities of the producers; however, they are not yet fully present, so they may be reinforced through interventions or training. Although in some cases, these innovations exceed 50 % of knowledge, there is still a gap with the Pln, which can be addressed with interventions.

Wide technological gaps were found in some mapped innovations, which require further study to understand the situation that leads to their existence. Such activities were related to A2 soil amendment techniques: lime, sulfur, manure, G24 sun drying process and G25 machine drying process.

In the activities where the knowledge and practice index is higher than 0.50, promotion is not necessary, because at that presence level, the innovations can no longer be influenced; therefore, the practice must reach the producers. These innovations are B5 monitoring of pests and diseases, C10 combination of allspice with other crops, C11 specifications for plantation establishment, G21 harvest and selling of allspice programming, G22 tools for harvesting facilitation, G23 sale of fresh allspice. This represents an area of opportunity to rethink these activities, towards the generation of innovations that create value for the producers; and therefore the improvement of the current forms of production.

The results show that in the presence of other crops, allspice occupies smaller surfaces; in production systems with more than two crops, it occupies even less area; in systems where there are two crops, allspice occupies a larger area. This difference could be explained by the economic contribution of the crops and the role played by each of those that make up the production system.

The above concurs with that reported by Ayala-Garay *et al*. (2016) who found that the interaction of surfaces and the presence of profitable crops can displace those that are not and such a condition may be determined by the emplaced agronomic practices.

The analysis found that the categories: marketing, organization and administration have the lowest rates of knowledge and practice. Within these, it was possible to detect that consolidated purchases and sales are not taking place, the hiring of advisory services, the management of the plantation, and the recording of the quality and quantity of the product. Previous studies in other crops showed that the organization is the category with the least adoption by producers (Andrade-Saavedra *et al*., 2019; Vargas-Canales *et al*., 2018).

The three least practiced categories correlate, since consolidated sales cannot be generated against intermediaries if there is no organization, nor can prices be negotiated if there are no quality records. These puts allspice producers at a disadvantage in obtaining resources for their development. Regard the above, there are studies that affirm that disorganization leads producers to a fragile profitability and little negotiating power (Ayala-Garay *et al*., 2014; García-Sánchez *et al*., 2018; Jaramillo, 2014).

The results show that the greatest gap categories are: harvest, sustainable management and plantation establishment, agronomic management and nutrition. In contrast, González-Cruz (2019) reported that, in the case of allspice producers at the state of Puebla, Mexico, the least adopted category corresponds to nutrition; and categories such as sustainable harvesting and management are among the most emplaced. It was found that, in the harvest category, the innovation in the sun drying process has one of the largest gaps. Unlike these results, González-Cruz (2019) reports that producers at the state of Puebla are beginning to carry out sun-drying methods.

In order to insert the existing knowledge in the practices for allspice production, activities with lower knowledge levels and practices can be promoted; This contribute to the improvement of the productive state of the crop. There is evidence from Ayala-Garay *et al*. (2016)

and Muñoz-Rodríguez *et al*. (2007), that the adoption of innovations moves in tune with the increase in productivity.

Finally, the innovations that are in a higher than 0.5 position, are the area of opportunity to rethinking these activities towards innovations that offer advantages. As proposed by Rogers (1995), innovation must present: relative advantage, compatibility and complexity, both experimental and observable.

CONCLUSIONS

The secondary role played by allspice regard the amount of surface occupied in the plots and the presence of other commercial crops already developed may be the explanation of why allspice have remained in its current productive state. There are producers who are already entering a better-established cultivation system and management, different from conventional; these are the producers that present an index of knowledge of innovations with opportunity areas; In the same sense, these are the producers who also present the indexes of practice of the innovations different from those already carried out by most of the producers.

By understanding the technological aspects in the production process of allspice, the areas that need to be rethought are evident, as well as which ones need to be promoted; with the proposed mapping, it is possible to identify the activities that already flow into what to do for the producers, as well as those that are not yet fully circulating among their knowledge and practices.

The existing gap of practical knowledge can be an area of opportunity for intervention, so that these indices increase, the differentiation of the indices in proposed groups can be the first way to this end.

REFERENCES

Andrade-Saavedra, Z. X., Ocampo-Ledesma, J. G., Aguilar-Ávila, J., & Palacios-Rangel, M. I. (2019). Resiliencia en empresas de agricultura protegida. La situación en Yecapixtla, Morelos, México. [Universidad Autónoma Chapingo]. http://repositorio.unan.edu.ni/2986/1/5624.pdf

Ayala-Garay, A., Espitia-Rangel, E., Rivas-Valencia, P., Almaguer-Vargas, G., & Preciado-Rangel, P. (2014). Análisis del sistema productivo de amaranto en Temoac, Morelos, México. Ciencia Ergo Sum, 23(1), 49–57.

Ayala-Garay, A., Espitia-Rangel, E., Rivas-Valencia, P., Martínez-Trejo, G., & Almaguer-Vargas, G. (2016). Análisis de la cadena del valor de amaranto en México. Agricultura Sociedad y Desarrollo, 13(1), 87. https://doi.org/10.22231/asyd.v13i1.280

Claridades Agropecuarias. (2001). La pimienta una especia milenaria, en un mercado especial. InfoAserca, 96, 28. http://www.infoaserca.gob.mx/claridades/revistas/096/ca096.pdf

CONABIO. (1947). Pimenta dioica. Contributions from the Gray Herbarium of Harvard University, 37(1), 198–200. https://doi.org/10.1021/np0705615

García-Sánchez, E. I., Vargas-Canales, J. M., Palacios-Rangel, M. I., & Aguilar-Ávila, J. (2018). Sistema de innovación como marco analítico de la agricultura protegida en la region centro de México. Cuadernos de Desarrollo Rural, 15(81), 1–24. https://doi.org/https://doi.org/10.11144/Javeriana.cdr15-81.sima

Gómez, J. R. (2007). Propagación de la pimienta de Jamaica (*Pimenta dioica*) por estacas terminales con hojas.

González-Cruz, M. (2019). Estrategia comercial para pequeños productores de pimienta gorda de la sierra norte de Puebla. Universidad Autónoma Chapingo.

Jaramillo, V. J. L. (2014). Evaluación y determinación de la escala mínima rentable, de unidades productivas para emprendedores en el campo poblano (1st ed.). Colegio de postgraduados.

Lim, T. K. (2012). Edible Medicinal and Non Medicinal Plants. In Fruits (Vol. 3). https://doi.org/10.1007/978-94-007-2534-8

Macia Barco, J. M. (1998). La pimienta de Jamaica (*Pimenta dioica* (L.) Merrill, Myrtaceae) en la sierra norte de Puebla (México). Anales Jardin Botanico de Madrid, 56(2), 337–349.

Martínez-Pérez, D., Hernández-García, M. A., & Martínez-González, E. G. (2013). La pimienta gorda en México (*Pimienta dioica* L. Merril): avances y retos en gestión de la innovación (1st ed.). Universidad Autónoma Chapingo (UACh), Centro de investigaciones económicas, sociales y tecnológicas de la agroindustria y la agricultura mundial (CIESTAAM). https://doi.org/10.13140/RG.2.1.3644.2080

Monroy Rivera, C. R. (2011). Paquete Tecnológico Pimienta Gorda (*Pimenta dioica* L . Merril) Establecimiento y mantenimiento (1st ed., Vol. 1). INIFAP.

Morales, M. (2008). Hierbas y especias más utilizadas en México. 39(5), 561–563.

Muñoz-Rodríguez, M., Aguilar-Ávila, J., Rendón-Medel, R., & Altamirano-Cárdenas, J. R. (2007). Análisis de la dinámica de innovación en cadenas agroalimentarias. In Materiales de formación para las agencias de gestión de la innovación (Primera ed, Vol. 53, Issue 9). Universidad Autónoma Chapingo (UACh), Centro de investigaciones económicas, sociales y tecnológicas de la agroindustria y la agricultura mundial (CIESTAAM). https://doi.org/10.1017/CBO9781107415324.004

Muñoz-Rodríguez, M., Altamirano-Cárdenas, J. R., Aguilar-Ávila, J., Rendón-Medel, R., García-Muñiz, J. G., & Espejel-García, A. (2007). Innovación: motor de la competitividad agroalimentaria. Políticas y estrategias para que en México ocurra. CIEESTAAM/PIAI. Universidad Autónoma Chapingo. México.

Odame, H. S., Owuo, J. B. O., Changeh, J. G., & Otieno, J. O. (2020). The role of technology in inclusive innovation of urban agriculture. Curr Opin Environ Sustain, x(41), 1–6. https://doi.org/10.1016/j.cosust.2019.12.007

Rao, P. S., Navinchandra, S., & Jayaveera, K. N. (2012). An important spice, *Pimenta dioica* (Linn .) Merill: A Review. International

Current Pharmaceutical Journal, 1(8), 221–225. https://doi.org/10.3329/icpj.v1i8.11255

Rema, J., & Krishnamoordthy, B. (2012). Allspice. Woodhead Publishing Limited, 166–192. https://doi.org/10.1533/9780857095688.166

Reyes-Martínez, A. (2017). Chiapas exportando pimienta gorda. IICA.

Rogers, E. M. (1995). Diffusion of innovations. In Macmillian publishing co. (3rd ed.). The Free Press. https://doi.org/citeulike-article-id:126680

Sol-Sánchez, Á., López-Juárez, S. A., Córdova-Ávalos, V., & Gallardo-López, F. (2018). Productividad potencial del SAF cacao asociado con árboles forestales. Revista Iberoamericana de Bioeconomía y Cambio Climático, 4(7), 862–877. https://doi.org/10.5377/ribcc.v4i7.6327

Ullah, A., Arshad, M., Kächele, H., Khan, A., Mahmood, N., & Müller, K. (2020). Information asymmetry, input markets, adoption of innovations and agricultural land use in Khyber Pakhtunkhwa, Pakistan. Land Use Policy, 90(xxx), 104261. https://doi.org/10.1016/j.landusepol.2019.104261

UTE-Innovación (Unidad Técnica Especializada en Gestión de la Innovación). (2013). Informe de operación 2012. Proyecto Estratégico Trópico Húmedo. CIESTAAM - UACh, México.

Vargas-Canales, J. M., Palacios-Rangel, M. I., Aguilar-Ávila, J., Camacho-Vera, J. H., Ocampo-Ledesma, J. G., & Medina-Cuellar, S. E. (2018). Efficiency of small enterprises of protected agriculture in the adoption of innovations in Mexico. Estudios Gerenciales, 34(146), 52–62. https://doi.org/10.18046/j.estger.2018.146.2811

Zainal, M., & Hamzah, S. R. (2018). Urban Agriculture: The Role of Knowledge among Farmer in Malaysia. International Journal of Academic Research in Business and Social Sciences, 7(14), 77–85. https://doi.org/10.6007/ijarbss/v7-i14/3653

Zhang, L., & L. Lokeshwar, B. (2012). Medicinal Properties of the Jamaican Pepper Plant *Pimenta dioica* and Allspice. Current Drug Targets, 13(14), 1900–1906. https://doi.org/10.2174/138945012804545641

https://doi.org/ 10.32854/agrop.v14i05.1881

Description of factors decreasing egg incubation of creole hens (*Gallus gallus domesticus*)

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ABSTRACT

Objective: To describe the factors that affect the incubation of fertile eggs of Creole hens (*Gallus gallus domesticus*) at Mezquital Valley, Hidalgo, Mexico.

Design/Methodology/Approach: 448 eggs of Creole hens were incubated in a Casser model 7622 incubator, in which the number of infertile and fertile eggs was evaluated; within the number of fertile eggs, the number of dead embryos was determined; due to dehydration or damage caused by fungi and bacteria. From the live hatched chickens, those that died due to omphalitis were recorded.

Results: 272 of 448 incubated eggs were fertile; 119 of them hatched and 153 were dead embryos. While 176 were infertile. Among the dead embryos, 84 of dehydration, 69 due to fungal and bacterial infection and 11 live hatched chicks due to omphalitis.

Limitations/implications: The literature review found little information on factors affecting the hatching of fertile Creole chicken eggs in backyard flocks.

Findings/conclusions: Infection by fungi and bacteria increase embryonic mortality, while omphalitis increases mortality during the first days of life of the backyard Creole chickens. High storage temperature in the nest or incubator causes embryo dehydration.

Keywords: embryonic mortality, bacteria, fungi, dehydration, egg infertility.

INTRODUCTION

Backyard poultry farming is an important livestock activity in rural communities in Mexico. This activity strengthens the welfare of low-income families because it provides animal protein and economic income. Creole hens (*Gallus gallus domesticus*) are the predominant birds for backyard poultry farming; however, they face the problems of being displaced by genetically improved lines of birds, not adapted to the environments of traditional management (Rodríguez-Ortega *et al.*, 2019). Another problem is the lack of technical management during their incubation process, which decreases hatchability and the number of live chicks. Temperature, humidity,

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ventilation, poor sanitary management of the birds and facilities, as well as bacterial and fungal infections are factors that decrease the hatchability of the fertile egg of Creole hens (Rodríguez-Moya *et al*., 2017). French (2009) mentioned that the optimum temperature for good embryo development is between 37 and 38 °C, while the embryos immediately die when exposed to 47 °C. In contrast, embryos can withstand low temperatures for short periods, cold reduces yolk consumption by the embryo, which affects its survival (Hussain *et al*., 2019). Relative humidity inside the incubators significantly influences embryonic mortality and development. Van der Pol *et al*. (2013) reported that relative humidity between 30 and 35% increased embryonic mortality and decreased hatching, and that, low relative humidity inside the incubator leads to increased water evaporation from the egg, causing embryonic dehydration (Noiva *et al*., 2014) and consequently egg weight decreased decreases the live chick's weight. Also, bacteria and fungi reduce avian hatch are in all areas of a farm; nest, floor, manure and the dust particles in the air (Bakheet *et al*., 2017). Both pathogens penetrate the egg through the pores of the eggshell during incubation. *Salmonella* spp. is one of the bacteria with the highest presence in the eggshells (Spickler *et al*., 2011), *Escherichia coli* is another pathogenic bacteria that causes embryonic death if it gets through the pores of the eggshell (Khan *et al*., 2016). Microscopic fungi such as *Aspergillus fumigatus*, *Fusarium culmorum* and *Fusarium equiseti* penetrate the egg and consequently, embryos become contaminated with spores and mycelium and die (Tomczyk *et al*., 2018). Based on the above, the factors that affect the incubation of the fertile egg of Creole chickens (*Gallus gallus domesticus*) at the Mezquital Valley, Hidalgo, Mexico.

MATERIALS AND METHODS

The research took place at the poultry facilities of the Universidad Politécnica de Francisco I. Madero (UPFIM), located in Tepatepec, Hidalgo, Mexico, at 1900 meters above sea level. The climate of the region is dry with an annual temperature ranging from 7 °C to 27 °C. A total of 448 eggs were incubated in an incubator model Casser 7622. The temperature was maintained at 37 °C and 55% relative humidity for 21 days. Before placed in the incubator, the eggs were individually cleaned with water without any disinfectant and dried with paper napkins. Relative humidity was provided by a glass container with clean water; the water was daily rechanged.

At 20 days, the eggs with embryo presence were determined by light impairment. For this, a lamp was used and the movement or shade of the embryos was observed. Infertile eggs allowed full light passage and were removed from the incubator then opened to confirm the diagnosis. The selected fertile eggs were placed in the hatcher section until day 23, during this time the number of hatched chicks was recorded. The eggs that did not hatch were opened to determine the factor that prevented their hatching. By visual inspection, it was determined if they were dehydrated or infected by fungi or bacteria. The hatched chicks were placed in a pen on a 4 cm thick oat straw flooring, the straw particle size was 2 cm commercial feed for young stage chickens and water *ad libitum* was provided. The temperature was constant at 30 °C during the first seven days of life, dead chicks were recorded and checked to determine the cause of death, yolk sac infection (omphalitis) was determined following the characteristics described by Khalaf *et al*. (2015).

The fertile egg percentage was determined as follows: [(number of fertile eggs/total eggs number) × 100]. The embryo percentage was calculated as: [(number of eggs with embryo/number of total eggs) × 100]. While the hatched chicks percentage was calculated as: [(number of hatched chicks/number of total eggs) × 100]. The percentage of dehydrated embryos was calculated as: [(dehydrated embryos/dead embryos) × 100]. The percentage of bacterial and fungi infection was calculated as: [(number of infected embryos/number of dead embryos) × 100]. The mortality percentage due to yolk sac infection was calculated as: [(number of dead chicks due to yolk sac infection/number of hatched chicks) × 100]. Data were analyzed with the PROC PRINT, PROC and UNIVARIATE Procedure of SAS v 9.0 (SAS, 2011).

RESULTS AND DISCUSSION

In this research, we observed that the prolonged storage of fertile eggs in backyard production is a factor that affects their incubation, due to the uncertainty of the eggs hatching time. 61% of the eggs collected from the backyard production system were fertile, 27% of them hatched and 34% were dead embryos. While 39% were infertile (Table 1).

In backyard poultry farming, eggs are stored for varying lengths of time until enough are available to maximize the hatchery space. Eggs are usually stored for more than two weeks before their incubation. This may be a factor that decreased the number of hatched chicks (Table 1). The storage temperature is also an important factor involved in hatchability. Addo *et al*. (2018) observed that storage temperatures above 23 °C for more than 14 days increased embryonic mortality. In backyard systems, the fertile eggs are stored at room temperature with no care on the climate variability, this could have also been an important cause in the embryonic mortality observed in this research (Table 1).

Table 1. Number of infertile eggs, dead embryos, and hatched chicks.

Variable	Number of eggs	(%)
Infertile eggs	176	39
Dead embryos	153	34
Hatched chickens	119	27
Total	448	100

Incubation is one of the most important activities in backyard poultry farming; however, multiple factors decrease fertile egg's hatchability. Bacteria and fungi are the factors that decrease embryo survival, and high embryonic mortality affects the number of backyard poultry in rural areas of Mexico. In this research, we found that the major cause of embryo death was dehydration, but bacterial and fungal infections also drastically affected embryos (Figure 1). Omphalitis was the main death cause during the first days of life of live-born chicks (Table 2).

Excessive water loss is lethal for embryos, dehydrating and preventing them from hatching (Walsh *et al*., 1995). In this research, we observed that the eggshell membranes were attached to the embryo due the dehydration, which means that lack of moisture is a factor in increasing the number of dead embryos (Table 2). Temperature and humidity inside the incubator also affect the egg's water loss; however, dehydration can be generated outside the incubator during the egg's storage or in the nest, due to the late collection time, which increases its exposure to environmental variability.

Eggs with green mold inside were recorded (Figure 1 A) these did not have a bad odor. In contrast, eggs with black inside had a strong-bad odor (Figure 1 B). Among the embryos that did not hatch, it was observed that the yolk sac was not absorbed and was strongly vascularized by the vitelline veins (Figure 1 C), while in the chicks that hatched and died in the first days of life, it was observed that the navel had poor scarring, their belly was swollen and dark green (Figure 1 D).

Ameen *et al*. (2017) observed that optimal conditions for fungus spores development of *Aspergillus* genus are adequate in the incubator. Due to the high relative humidity (55%) and temperature (37 °C), the spores penetrate through the pores of the eggshell until they reach the yolk, which is an ideal substrate for their development. In this research, we report the total number of eggs with the presence of dark green mold and foul odor, thus indicating the presence of a pathogenic microorganism (Table 2 and Figure 1 A and B). Jacobsen *et al*. (2010) reported that *Aspergillus fumigatus* and *Aspergillus flavus* are the most frequently found pathogens in fertile hatching eggs. Infected eggs develop green mold, this description coincides with the mold that developed in the egg in Figure 1 A. Higenyi *et al*. (2014) observed that *Pseudomonas* spp., *Staphylococcus aureus*, *Escherichia coli* and *Salmonella* spp. are the bacteria with the highest presence inside hatching fertile eggs, which reduces hatchability and increases embryonic mortality. The presence of these bacteria is due to poor sanitary management in the backyard systems. The egg infected by bacteria in this research presented a foul odor, coinciding with Orel (1959) who reported that the eggs infected by *Pseudomonas* had a bad odor: putrid or sour and was, therefore, the field characteristic that confirmed the presence of a bacterial infection (Figure 1 B). AL-Ashmawy *et al*. (2013) reported that *Pseudomona aeruginosa* inside the eggs causes a putrid odor.

Table 2. Causes of death of embryos and live hatched chicks.

Cause of death in embryos		
Variable	Number of cases	(%)
Dehydrated	84	55
Bacterial and fungal infection	69	45
Total	153	100
Cause of death in live born chickens		
Omphalitis	11	9
Healthy hatched chickens	108	91
Total	119	100

The infection of the yolk sac is the main death cause during the first week of the life of chicks. Bacteria cause deterioration and decomposition of the yolk, depriving the chick of essential nutrients (Figure 1 C). The yolk is also the main source of immunity that the parent transmits to its progeny; if the yolk is affected, the ability to resist diseases reduces. Amare *et al*. (2013) observed that the main bacteria causing yolk sac infections *Escherichia coli*, *Staphylococcus aureus* and *Proteus mirabilis*, the infection increases the size of the yolk and reduces its absorption, their symptom is a green color with a brownish cloudy liquid and foul odor. Chicks present low body weight, a large, wet and improperly closed umbilical cord and blackened umbilicus and sometimes a foul-smelling crust (Khalaf *et al*., 2015). Based on the characteristics described above, the birds in Figure 1 C and D showed yolk sac infection. This infection is considered an important factor that decreases chick development in the first days of life (Table 2).

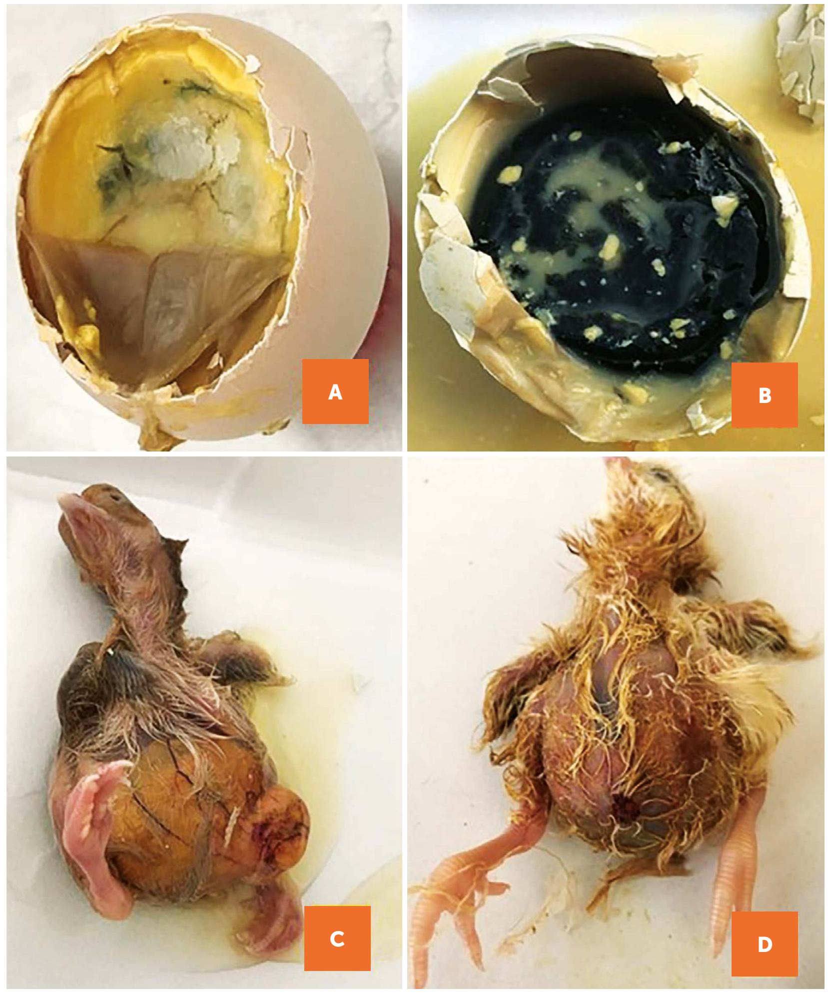

Figure 1. Factors affecting the incubation of the fertile eggs of Creole hens and the development of their chicks, A; green mold inside, which indicated a fungal infection, B: egg with black inside and strong odor, which revealed the presence of bacteria, C: chick with poor absorption of the yolk sac, D: chick with poor healing of the umbilicus and dark green belly.

CONCLUSIONS

Dehydration, fungal and bacterial infections increase embryonic mortality infertile eggs of Creole hens, while yolk sac infection increases mortality in the progeny, affecting the replacement in backyard poultry farming systems. External factors such as storage time, temperature and poor pen hygiene affect the hatchability of Creole hen eggs. Future research on backyard chicken in Mexico should focus on characterizing the fungi and bacteria present in Creole hen eggs, to design possible sanitation strategies to reduce embryonic mortality.

REFERENCES

Addo, A., Hamidu, A. J., Yaw, A. A., Adomako K. (2018) Impact of Egg Storage Duration and Temperature on Egg Quality, Fertility, Hatchability and Chick Quality in Naked Neck Chickens. International Journal Poultry Science 17(4): 175-183.

AL-Ashmawy, M. A. M., El-Galil, K. A., Elwsaifi, S. F. (2013) The microbial burden of *Pseudomonas* species in different types of table eggs in Egypt. World Journal of Dairy and Food Sciences 8(2):190-195.

Amare, A., Mohammed, A. A., Shiferaw, A., Nazir, S., Negussie, H. (2013) Yolk Sac Infection (Omphalitis) in Kombolcha Poultry Farm, Ethiopia. American-Eurasian Journal of Scientific Research 8 (1): 10-14.

Ameen, A. M., Mustafa, S. O., Hassan, D. R., Rajab, D. A., (2017) The Effect of Aspergillus Fungi, Other Fungus, and Isolated *Salmonella* and *E. coli* Bacteria on Poultry Farms and Poultry Hatcheries at Veterinary Laboratory in Veterinary Directorate in Duhok, Kurdistan Region of Iraq. EC Microbiology 5.2:52-58.

Bakheet, A. A., Ali, N. M., Habaty S. H. A., Nasef, S. A. (2017). Detection of Disinfectant resistant aerobic bacteria in unhatched chicken eggs. Benha Veterinary Medical Journal 2; 32 (2): 248- 259.

French, N. A. (2009). The critical importance of incubation temperature. Avian Biology Resch; 2 (1/2): 55-59.

Higenyi, J., Kabasa, J. D. (2014). Microbial contamination load of hatching eggs in Butaleja, eastern Uganda. Animal and Veterinary Sciences; 2(2): 22-30.

Hussain, A., Bilal, M., Habib, F., Gola, B. A., Muhammad, P., Kaker, A., Yousaf, A., Khalil, R. (2019). Effects of low temperature upon hatchability and chick quality of ross-308 broiler breeder eggs during transportation. Online Journal of Animal Feed Research 9(2): 59-67.

Jacobsen, D. I., GroBe, K., Slesiona, S., Hube, B., Berndt, A., Brock, M. (2010). Embryonated eggs as an alternative infection model to investigate *Aspergillus fumigatus* virulence. Infection and Immunity 78(7): 2995-3006.

Khalaf, J. Z., Hamed, F. W., Yassien, I. Z., Nazar, J. B. (2015). Bacteriological and pathological study of omphalitis in broiler chicks. Kufa Journal for Veterinary Medical Sciences 6(2): 17-26.

Khan, A., Rind, R., Shoaib, M., Kamboh, A. A., Mughal, G. A., Lakho, S. A., Malhi, K. K., Nizamani, A. R., Yousaf, A. (2016). Isolation, identification and antibiogram of *Escherichia coli* from table eggs. Journal of Animal Health and Production 4(1): 1-5.

Noiva, R. M., Menezes, A. C., Peleteiro, M. C. (2014). Influence of temperature and humidity manipulation on chicken embryonic development. BMC Veterinary Research 10(234):1-10.

Orel, V. (1959). The Spfoilage of Eggs Infected by *Pseudomonas* Bacteria and Different Methods of Preservation. Poultry Science 38 (6): 1302-1308.

Rodríguez-Ortega, L. T., Valladares-Hernández, Á. C., Vargas-Monter, J., Callejas-Hernández, J., Pro-Martínez, A., Vargas-Galicia, A. J., Sosa-Montes, E., González-Cerón, F., Rodríguez-Ortega, A. (2019). Evaluación del desarrollo de pollitas araucanas (*Gallus inauris* Castelló) y marans (*Gallus gallus domesticus* L.). Agroproductividad; 12 (8): 79-83.

Rodríguez-Moya, J., Cruz-Bermúdez, A. I. (2017). Factores que afectan la incubabilidad de huevo fértil en aves de corral. Nutrición Animal Tropical 11(1): 16-37.

SAS Institute Inc. (2011). SAS user's guide: statistics version. SAS Institute Inc., Cary, NC, USA. 959 pp.

Spickler, J. L., Buhr, R. J., Cox, N. A., Bourassa, D. V., Rigsby, L. L. (2011). Comparison between rinse and crush-and-rub sampling for aerobic bacteria recovery from broiler hatching eggs after sanitization. Poultry Science; 90:1609-1615.

Tomczyk, L., Stepién, L., Urbaniak, M., Szablewski, T., Cegielska-Radziejewska, R., Stuper-Szablewska, K. (2018). Characterisation of the Mycobiota on the Shell Surface of Table Eggs Acquired from Different Egg-Laying Hen Breeding Systems. Toxins 10(293):1-10.

van der Pol, C. W., van Roovert-Reijrink, I. A. M., Maatjens, C. M., van den Brand, H., Molenaar, R. (2013). Effect of relative humidity during incubation at a set eggshell temperature and brooding temperature posthatch on embryonic mortality and chick quality. Poultry Science 92:2145–2155.

Walsh, T. J., Rizk, R. E., Brake, J. (1995). Effects of temperature and carbon dioxide on albumen characteristics, weight loss, and early embryonic mortality of long stored hatching eggs. Poultry Science 74:1403-1410.

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Agronomic behavior and fruit quality in habanero peppers (*Capsicum chinense* Jacq.) as a response to formative pruning

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ABSTRACT

Objective: To evaluate the effect of pruning on the agronomic variables and fruit quality of habanero peppers (*Capsicum chinense* Jacq.).

Methodology: Habanero peppers were pruned with two intensities, two shoots and three shoots. The control plants were not pruned. The experiment had a randomized block design with four replications. The experimental plots consisted of 50 plants established in rows at a distance of 1.2 m and 0.3 m among plants within a row. The evaluated variables were fruit yield, number of fruits per plant, fruit weight, fruit length and fruit diameter. Data were obtained from 10 harvests. For the analysis, the fruit quality, ash content, moisture, protein and crude fiber were determined.

Results: Plants with two and three shoots produced fruits of 4 and 3.99 cm in length. Plants with two and three shoots produced 42 and 48% first quality fruits, whereas control plants produced only 10% first quality fruits. The highest protein content in fruits at physiological ripeness (14%) and commercial maturity (12%) was observed in plants pruned to two shoots.

Implications: These results show the importance of crop management on the fruit quality of habanero peppers. Further studies are needed to have more information on the effects of crop management on the nutritional content of fruits.

Conclusion: The pruning of habanero pepper plants significantly influenced the fruit size, crude fiber and protein content in their fruits.

INTRODUCTION

Habanero peppers (*Capsicum chinense* Jacq.) are in demand in the national and international market. In this sense, it is sown in 20 states in Mexico, with a total of 971.45 ha and a production of 16,306.31 t. The largest planted area is mainly found in the southeast region the country. The state of Yucatán is the main producer of habanero peppers, with 243.24 planted ha and a production volume of 3,222.84 t, and an average yield of 13.69 t ha^{-1}. Followed by the states of Tabasco, Quintana Roo, Campeche and Chiapas. In Yucatán, 40 municipalities produce habanero peppers,

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of which ten are the ones with the largest planted area. The municipalities of Tahdziú, Halachó, Yaxcaba, Tekax, Peto and Tizimín stand out, concentrating 60% of the production of habanero peppers in the state of Yucatán (SIAP, 2019). Even though it is the region with the largest cultivated area of habanero peppers, its yields do not cover the overall demand, mainly for sauces and condiments production, since the crop is strongly affected by inadequate planning, which limits the production and quality of their fruits (Reyes-Ramírez *et al*., 2014). The three main factors that must be taken into account when planning a crop are: pest and disease control, nutrition and agronomic management (Reyes-Pérez *et al*., 2019). Within the latter, training pruning allows to define the plant development according to the number of stems that it is desired to have, which facilitates cultural operations, treatments, harvesting, staking and can influence the yield and quality of the fruits (Villa *et al*., 2014). The cultivation of habanero peppers is generally sown following a traditional open-field system. However, with this system, the crop is negatively affected on the quality and yield of their fruits due to the fact that agronomic management given in the field is sometimes limited (Lugo-Jiménez *et al*., 2010). In this way, it is important to identify the factors that influence the production and quality of the habanero peppers, in such a way that yields increases are guaranteed and with it, its commercialization. The yield and quality of the habanero pepper fruits were evaluated as a response to formation pruning.

MATERIALS AND METHODS

Establishment and crop management

The work took place at Conkal, Yucatán (21° 15′ N and 83° 32′ W). The region›s climate is AW0 type, warm subhumid with an annual mean rainfall of 984.4 mm and an annual mean temperature of 26.8 °C. The experimental habanero pepper variety H-241 with orange fruits was assessed. The sowing was carried out in 200 cavities polystyrene trays, previously disinfected with 5% chlorine. Cosmopeat® was used as a substrate. The seedlings management consisted of daily irrigation, in addition to the application of fungicide, insecticide and foliar fertilizer according to their needs.

The experiment was carried out in a greenhouse 40 m long by 18 m wide. The sowing was in 12 L capacity polyethylene bags filled with a substrate (soil + gravel) at a 10: 2 ratio. Substrate disinfection was carried out with hydrogen peroxide. Transplantation was carried out when the seedlings reached a height between 15 to 20 cm, approximately 42 days after sowing (dds). A completely randomized block with four repetitions was used. The useful plot was n=50 habanero pepper plants and the treatments consisted of three types of pruning: two-branch pruned per plant (T1), three-branch pruned plant (T2) and non-pruned plants (four branches) which was the control. Pruning was carried out 45 days after transplant (DDT). For irrigation, self-compensating and anti-draining drippers were used at a 4 L h^{-1} rate, with tees, tubines and irrigation stakes. The irrigations were daily applied, with a 40 min duration, divided into four irrigation frequencies of 10 min (9:00 am, 11:00 am, 1:00 pm and 3:00 pm).

Fertigation was applied using a 100 times concentrated stock solution through four tanks: A (acid), B (sulfates and phosphates), C (nitrates) and D (microelements). The used fertilization formula was: NO_3=12 meq, H_2PO_4=1.5 meq, K=7 meq, Ca=5 meq, Mg=2.5 meq, SO_4=2.5 meq, NH_4=1.7 meq, Fe=17 ppm, Zn=20 ppm, B=5 ppm and Mn=5 ppm per plant (Soria, 2002).

Agronomical variables

Fruit yield. It was determined in g per plant for 10 fruit cuts. **Number of fruits per plant**. Number of total fruits harvested in 10 plant cuts. **Individual fruit weight**. The average fruit weight (g) was obtained by dividing the fruit yield by the number of fruits per plant, the average fruit weight was reported throughout the harvest period. **Fruit length and diameter**. Ten fruits taken at random from each cutting were measured with a digital vernier (Figure 1).

Figure 1. Habanero pepper plants pruned to two branches with fruits at two maturity stages (green and orange color).

Fruit quality variables

Analyses were carried out at two stages of the fruit's maturity, taken from the experiment established under controlled conditions. For each variable, there were three replicates. The first analysis was made with green fruits (physiological maturity) taken from the fourth cut, approximately at 105 DDT. The second analysis was made with mature fruits (orange color) taken from the sixth cut, approximately at 125 DDT. For the analyses, 250 g of fruit were harvested per repetition, which resulted in 1.0 kg of fruit, before the chemical analyses, the samples were washed in running water and 1% sodium hypochlorite, allowed to dry at room temperature and then placed in an air convection oven at 60 °C for 72 h, after removing the peduncles. The whole fruits were crushed in a mill (Ika® Werke mod Mf 10 basic) and kept in a desiccator with silica until the corresponding analyses were done.

Moisture, ash, protein and crude fiber content were determined via bromatological analysis following the official methods of the AOAC (2000). Moisture was determined by gravimetric measurement using an air convection oven at 105 °C for 4 h, ash content was determined by muffle calcination at 600 °C for 4 h, while the amount of protein was calculated from the total nitrogen content with the Kjeldahl method (nitrogen to protein conversion factor 6.25). Crude fiber content was determined by the filter paper bag method, which uses acid digestion with H_2SO_4 (1.25%) and alkaline digestion with NaOH (1.25%) in a ANCON fiber analyzer.

Data analysis

An analysis of variance (ANOVA) was performed with the data, followed by a Tukey mean test at $p<0.05$.

RESULTS AND DISCUSSION

Agronomic performance

Differences ($p<0.05$) were observed in the fruit length, moisture, protein and crude fiber variables; while fruit yield, number of fruits per plant, weight, diameter and ash content were statistically equal. Based on the mean yield behavior, the three-branch pruning treatment numerically stood out with 1357 g per plant (Table 1). In this sense, Villa *et al*. (2014) evaluated the yield of habanero peppers with three training pruning (two, three and four stems). Plants pruned to three branches had yields of 5.37 kg m^{-2}, while unpruned plants (four branches) had yields of 4.59 kg m^{-2}. In contrast to the above, Monge-Pérez (2016) reported higher yields when bell chili pepper plants were not pruned.

For the number of fruits per plant, numerically, the highest value (165.57 fruits per plant) was recorded in plants pruned to three branches, while unpruned plants (four branches) obtained an average of 152.60 fruits per plant (Table 1). In this regard, for individual fruit weight, little variation was observed, which was not significant, where plants pruned to two branches had an average weight of 8.83 g per fruit and unpruned plants (four branches) 8.65 g per fruit. In contrast, Monge-Pérez (2016) found differences ($p<0.05$) in two pruning intensities (Spanish and Dutch) for the quality of square bell pepper (*C. annuum* L.).

Spanish pruning (two guides) increased 10% fruit weight (180 g), while with Dutch pruning (no pruning) the weight was 163.96 g. Villa *et al*. (2014) mentioned that the average fruit weight is higher as the number of stems per plant decreases, which constitutes a quality improvement. Likewise, Gómez *et al*. (2020) confirmed the aforementioned by evaluating the effect of different pruning intensities on two types of chili peppers (*C. annuum* and *C. chinense*); they reported an increase in the fruit weight.

The longest fruits were recorded in plants with two and three branches, in contrast to the unpruned plant, which had shorter fruits. For fruit width, numerically, the fruits in three-branch plants stood out with 3.11 cm, while the plants without pruning presented fruits 3.06 cm wide (Figure 2). In this regard, Gómez *et al*. (2020) found no differences ($p<0.05$) in habanero peppers regard the pruning treatments. However, in plants with two and

Table 1. Mean behavior and significance of agronomic variables as a response to pruning in habanero pepper plants.

Pruning system	Fruit yield (g $plant^{-1}$)	Number of fruits per plant	Individual fruit weight (g)
Two branches	1279.70±42.29a	148.03±6.69a	8.83±0.31a
Three branches	1357.00±33.24a	165.57±5.16a	8.24±0.13a
Four branches	1293.07±33.85a	152.60±5.23a	8.65±0.37a

Data include mean ± S.E., n=3. Means with the same letter are not statistically different between treatments, Tukey ($p\leq0.05$).

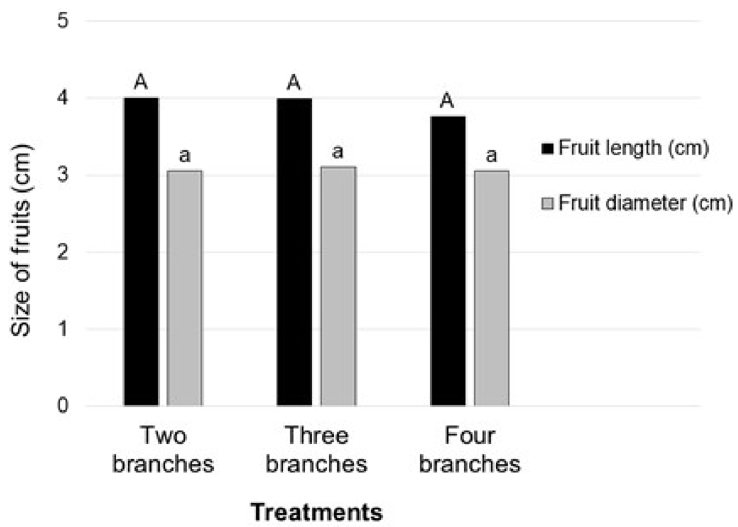

Figure 2. Size of habanero pepper fruits (length and diameter) according to formation pruning. Means with the same letter are not statistically different between treatments (p≤0.05).

three stems, the length and width of their fruits tended to be greater compared to those of unpruned plants.

In the present study, the quality of the fruit, regard their size was better than that reported in other research. In plants with two and three branches, fruits of 4.0 and 3.99 cm in length, respectively, and diameters of 3.11 and 3.06 cm, each, were produced. Overall, several studies have confirmed an increase in the size of the fruits in peppers when the plants are subjected to intensity of pruning, such is the case of Villa *et al*. (2014). The classification of the Official Mexican Standard NOM-189-SCFI-2017, defines three categories for the length of fruits: small (<2 cm), medium (2 to 3.9 cm) and large (>4 cm). In the present work, the plants pruned to two branches produced 42% first quality fruits (large fruits) and 48% second quality fruits (medium fruits); Regard the plants pruned to three branches, they produced 48% first quality fruits and 42% second quality (medium fruits), while the un-pruned plants (control) produced only 6% first quality fruits. The above indicates the importance of pruning on the quality of the fruits (Figure 3).

Fruit quality analysis

The results show that the humidity in green (physiological maturity) and orange (commercial maturity) fruits war not different (p<0.05) between pruned and un-pruned plants. The fruits at physiological maturity presented a higher percentage of humidity than those at commercial maturity (Table 2).

The humidity percentage results coincide with that reported by Morales-Guzmán (2013), who indicates that the humidity value of the chili fruits varies between 82% and 92%. High levels of humidity indicate that fruits are not adequate for long-term storage, because, during storage in low light conditions fungi growth and tissue decomposition favors by the activity of microorganisms and enzymes, affecting the nutritional and sensory properties. Additionally, the high water content in the fruits influences the

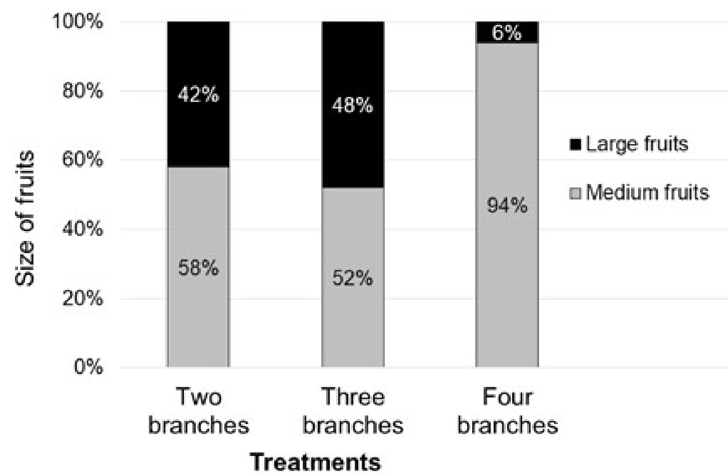

Figure 3. Percentage of first and second quality habanero chili fruits regard formative pruning.

Table 2. Bromatological analysis (humidity, ash, protein and crude fiber) of habanero pepper fruits as a response to formative pruning.

Ripening stage of fruits	Pruning system	Humidity (%)	Ash (%)	Crude protein (%)	Crude fiber (%)
Physiological ripeness	Two branches	91±0.002a	1±0.000a	14±0.000a	2±0.001a
	Three branches	90±0.000b	2±0.005a	13±0.003ab	2±0.001a
	Four branches	91±0.001ab	2±0.100a	13±0.000b	2±0.001a
Commercial ripeness	Two branches	86±0.010a	1±0.001a	12±0.003a	2±0.001b
	Three branches	86±0.010a	1±0.001a	12±0.002a	3±0.001a
	Four branches	86±0.003a	2±0.001a	10±0.010b	2±0.001b

[†]Means include ± S.E., n=3, means followed with the same letter are not statistically different between treatments (p≤0.05).

bioavailability of nutrients, since at high water content the nutrients contents can decrease (Solís-Marroquín *et al.*, 2017).

Regard the ash content of the fruits at physiological and commercial maturity as a response to pruning, no differences were found ($p>0.05$) (Table 2). In this regard, Solís-Marroquín *et al.* (2017) found higher ash values (6.5% in green fruits and 5.9% in orange fruits) in pepper (*C. annuum*) fruits of the cv. "siete caldos" grown in open field conditions at Comitán, Chiapas, Mexico. Although minerals were not quantified in this study, the *Capsicum* genus is considered an important and balanced source of a large number of essential nutrients, including mineral elements. The presence of minerals in the fruits could play a key role in the decrease of micronutrient deficiencies in humans (Olatunji & Afolayan, 2018). In this sense, Castillo *et al.* (2012) also confirm that a high ash content allows inferring that chili peppers are rich in mineral elements. Due to the obtained results in the ash content in the present study, it would be advisable to expand the analysis on minerals identification in habanero pepper fruits.

Differences ($p<0.05$) were observed for protein content due to pruning. It was observed that the fruits in physiological maturity showed a higher protein content than those at commercial maturity. Pruning management in plants with two and three branches statistically surpassed the non-pruned plants in their protein percentage. In fruits at physiological maturity of two pruned branches per plants, the protein content (14.0%) was statistically higher than in non-pruned plants; while in fruits at commercial maturity, the two pruning treatments statistically surpassed the protein content (12.0%) compared to the non-pruned ones (10.01%). This concurs with that reported by Alsadon *et al.* (2013) who argue that the competition for nutrients availability and other factors is lower in plants with fewer branches compared to plants with more branching. In this sense, Emmanuel *et al.* (2014) reported levels of 11.67% and 11.97% protein in *C. annuum* and *C. frutescens*, respectively. Rebouças *et al.* (2013), reported 4.8% protein content in *C. frutescens*, lower values than those found in the present study due to the pruning effect. Solís-Marroquín *et al.* (2017) reported a protein content of 13.9% in chili pepper fruits (*C. annuum*) and in habanero peppers (*C. chinense*). Likewise, Pino *et al.* (2010) found protein values of 14.92%, results that are similar to that found in this study.

In the crude fiber content, the effect of pruning was only different ($p<0.05$) in fruits at physiological maturity. An increase in the crude fiber content was observed in plants pruned to three branches (3.0%) compared to plants with two and four branches, which had 2.0% (Table 2). In this regard, Sandoval-Rangel *et al.* (2011) recorded 33.59% of fiber in "chile piquín" peppers (*C. annuum* var. *glabriusculum*) and Emmanuel *et al.* (2014) recorded 13.22% fiber in *C. annuum*, while Solís-Marroquín *et al.* (2017) reported 15.70% of crude fiber in green fruits of chile peppers cv. siete caldos, in the same way, they mention that a high content of crude fiber in chile peppers could reduce constipation in humans due to its water retention capacity, which causes an increase in the volume of intestinal waste.

CONCLUSIONS

Pruning in habanero pepper plants significantly influenced their fruit size (length and diameter), achieving a higher percentage of first quality fruits compared to unpruned plants. Yet, pruning did not affect the yield and number of fruits per plant. Based on the results of the fruit quality analysis, the habanero peppers are nutritionally valuable due to their mineral, protein and crude fiber content. Additionally, with the management of formation pruning, the protein content tends to increase.

REFERENCES

Alsadon, A., Wahb-Allah, M., Abdel-Razzak, H., Ibrahim, A. (2013). Effects of pruning systems on growth, fruit yield and quality traits of three greenhouse-grown bell pepper (*Capsicum annuum* L.) cultivars. Australian Journal of Crop Science. Vol. 7(9):1309-1316.

Association of Official Analytical Chemists (AOAC) (2000). 17th Edition. The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Castillo Y. M., Lares M., y Hernandez M. S. (2012). Caracterización bromatológica y fisicoquímica del fruto amazónico Asaí (*Euterpe precatoria* Mart). Vitae, Vol. 19(1): 309-311

Emmanuel, L. C., Peters H., Okiri O.A. (2014). Comparative evaluation of the nutritional, phytochemical and microbiological quality of three pepper varieties. Journal of Food and Nutrition Sciences, Vol. 2(3): 74-80.

Gómez, J. D. L., Nava, H. S., Torres, O. G. V., Rodríguez, M. A., & Taketa, A. T. C. (2020). Rendimiento y calidad del chile habanero en respuesta a la poda de conducción y régimen nutrimental. Revista Mexicana de Ciencias Agrícolas, Vol. 11(2): 315-325.

Lugo-Jiménez, N.; Carballo, B. M., Sauri, D. E., Centurión, Y. A. y Tamayo, C. E. (2010). Efecto del sistema de cultivo sobre la calidad microbiológica del chile habanero (*Capsicum chinense* Jacq.) después de su cosecha. México. Rev. Iberoamericana de Tecnología y Postcosecha, Vol. 11(2):171-179.

Monge-Pérez, J. (2016). Efecto de la poda y la densidad de siembra sobre el rendimiento y calidad del pimiento cuadrado (*Capsicum annuum* L.) cultivado bajo invernadero en Costa Rica. Tecnología en Marcha, Vol. 29(2): 25-136.

Morales-Guzmán, J. (2013). Evaluación de la producción y calidad de pimiento (*Capsicum annuum* L.) obtenido mediante biofertilización. Tesis de maestría en ciencia y tecnología de alimentos. Universidad Autónoma de Querétaro. 98 p.

Olatunji T. L., Afolayan A. J. (2018). The suitability of chili pepper (*Capsicum annuum* L.) for alleviating human micronutrient dietary deficiencies: A review. Food Science & Nutrition. 6:2239–2251.

Rebouças T., N.H., Valverde R., M.V., Teixeira H., L. (2013). Bromatologia da pimenta malagueta in natura e processada em conserva. Brasil. Horticultura Brasileira 31: 163-165.

Reyes-Pérez, J. J., Enríquez-Acosta, E. A., Ramírez-Arrebato, M. Á., Rodríguez-Pedroso, A. T., Lara-Capistrán, L., y Hernández-Montiel, L. G. (2019). Evaluación del crecimiento, rendimiento y calidad nutricional de pimiento con aplicación de Quitomax®. Ciencia e investigación agraria, Vol. 46(1): 23-29.

Reyes-Ramírez, A., López-Arcos, M., Ruiz-Sánchez, E., Latournerie-Moreno, L., Pérez-Gutiérrez, A., Lozano-Contreras, M. G., y Zavala-León, M. J. (2014). Efectividad de inoculantes microbianos en el crecimiento y productividad de chile habanero (*Capsicum chinense* Jacq.). Agrociencia, Vol. 48(3): 285-294.

Sandoval-Rangel, A., Benavides-Mendoza, A., Alvarado-Vázquez, M. A., Foroughbakhch-Pournavab R., Núñez-González, M. A. y Robledo-Torres, V. (2011). Influencia de ácidos orgánicos sobre el crecimiento, perfil bromatológico y metabolitos secundarios en chile piquín. Terra Latinoamericana, Vol. 29(4): 395- 401.

SIAP. (2019). Anuario estadístico de la producción agrícola. URL: http://nube.siap.gob.mx/cierreagricola/ (Consultado el 19 de febrero 2019).

Solís-Marroquín, D., Lecona-Guzmán, C. A., Ruiz-Lau, N., Ocampo, P., Rodas-Trejo, J., Gonzales-Santiago, C., y Gordillo-Páez, L. (2017). Análisis bromatológico de frutos de chile" siete caldos" (*Capsicum annuum*) cultivados en condiciones de cielo abierto y casa sombra. Agroproductividad, Vol. 10(9): 34-40.

Soria, F. M., Tun, S. J., Trejo, R. A., y Terán, S. R. (2002). Paquete tecnológico para la producción de chile habanero (*Capsicum chinense* Jacq.). SEP- DGTA- ITA-2. Instituto Tecnológico Agropecuario No.2, Conkal, Yucatán, México.

Villa C. M., Catalán V. E. A., Inzunza I. M. A., Román L. A., Macias R. H. y Cabrera R. D. (2014). Producción hidropónica de chile habanero en invernadero. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro Nacional de Investigación Disciplinaria en Relación Agua Suelo Planta Atmosfera. Folleto Técnico Num. 34. URL: https://aprenderly.com/doc/1896895/chile-habanero.indd

https://doi.org/10.32854/agrop.v14i05.1925

Hydrocarbons and heavy metals in Macuspana, Tabasco, Mexico: key stakeholders

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ABSTRACT

The objective of the research was through key actors to identify the contamination by hydrocarbons and heavy metals in water and the main sources of contamination in the municipality of Macuspana, Tabasco.

Methodology: A diagnosis was made, by applying questionnaires through interviews directed to the inhabitants of the municipality of Macuspana and workers in the oil sector. The data were processed with frequency analysis, Kruskal Wallis, analysis of variance, and multivariate with two factors.

Results: It was shown that there has been historical contamination, for 30 years, there is evidence of dead organisms in the water bodies, and the presence of various diseases in the population due to exposure to contaminants from hydrocarbons and heavy metals that derive from the oil activity. There is evidence of a negative impact due to the presence of spills from disabled wells due to a lack of maintenance programs.

Implications: The economy in most of the Gulf of Mexico is based on the extraction, processing, and distribution of hydrocarbons. This industry´s growth increased the number of exploration and production of oil wells, generating a direct impact on aquatic environments. The state of Tabasco is one of the largest oil producers, as well as fishing resources of commercial and environmental importance, which are directly affected by oil activity.

Findings: The study found cases of diseases in the population correlated with exposure to hydrocarbons.

Conclusions: There is little interest from the oil sector about public health problems in the population and environmental damage to the ecosystems in the municipality of Macuspana, Tabasco.

Keywords: Fishery resources, key players, oil.

INTRODUCTION

In Mexico, a volume of 1.6 to 2.2 million barrels of oil per day was produced from 2016 to 2020 (CNH, 2020). The state of Tabasco, Mexico, has the highest production of liquid hydrocarbons and gas (PEMEX, 2020). Tabasco has the most important land fields for the extraction and exploitation of hydrocarbons (INEGI, 2011), some of the most important is at the community of Macuspana, and the "Activo Integral de Producción de Samaria Luna", which have wells within this municipality in the "Bitzal" river and the "Reserva de la Biosfera de Los Pantanos de Centla".

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The Macuspana watershed is in southeastern Mexico and has an area of continental 7,300 km^2 and approximately 1,800 marine km^2 (Guzman and Aranda, 2002). One of the main ecological problems in modern society is the increasing pollution of natural resources as a result of anthropogenic activities, such as industrial activities, services, domestic activities, urban and agricultural activities, and the oil sector has grown at an accelerated rate due to the energy demand worldwide (González, 2009; Santana *et al*., 2012).

Hydrocarbons can be grouped into aliphatics (with 18 to 35 carbon atoms) and aromatics (with one or more benzene, naphthalene and phenanthrene rings). Polycyclic aromatics are of low molecular weight, formed with two or three aromatic rings, which makes their mobility in water easier (Murphy and Morrison, 2002; Acuña *et al*., 2010).

The hydrocarbons with the greatest effects on male reproductive function are halogenated, aromatic, phthalates, biphenyls, polychlorinated (PBS); toxic agents such as hydrocarbons can act on the hypothalamic-pituitary-testicular axis, directly affecting the male gamete, and causing alterations during fertilization, implantation and embryonic development (Romay and Pousa, 2019).

Worldwide, hydrocarbons that come from lakes, phreatic zones, rivers, and soil by biological and chemical processes are concentrated in the sea and oceans (Shahidul and Tamaka, 2004). It has been estimated that between 0.1 and 0.2% of the world's oil production is discharged into the sea, which represents about three million tons that pollute the sea annually (Reis, 1996).

In Chile, the sources of pollution associated with small boats using outboard motors are the cause of oil pollution on Robinson Crusoe Island (Bonert *et al*., 2006). There are reports of spills in the Gulf of Mexico from the Ixtoc-I well, off the coast of Campeche, where up to 3100 00 barrels of crude oil were dispersed in marine waters during 1978, which was considered the greatest impact worldwide; but hydrocarbon inputs to the ocean may have other sources of contamination. However, atmospheric transport, coal and wood-burning, and automobile combustion, which produce polycyclic aromatic hydrocarbons, may have other effects. Oil exploitation in the Gulf of Mexico in coastal regions, inhabited by large quantities of marine species such as fish, crustaceans and mollusks in the Atlantic coast, has ecologically impacted and altered the aquatic organisms communities, ecosystems and human habitat (Botello, 2005).

The state of Tabasco has been impacted in up to 0.07% of its total area by hydrocarbon contamination in the soil (Ferrera *et al*., 2006). For the population near the sectors of the PEMEX city gas processing complex in Mascupana, Tabasco, the oil industry has generated negative impacts and effects on biodiversity overall; among the identified activities, the generation of gas increases the concentration of greenhouse gases is of great impact. Gas treatment through compressors causes noise pollution, for the people living near the area and disturbs the flora and fauna; storage, transportation, and the dismantling of the site generate water and soil contamination that has impacts on biodiversity, in addition to acts of vandalism during the transportation of hydrocarbons through pipelines and have direct impacts on the health inhabitants (López *et al*., 2019). Because of the above, the contamination by hydrocarbons and heavy metals in the area by the use and consumption of water from different sources in the municipality of Macuspana, Tabasco, Mexico, was identified.

MATERIALS AND METHODS

The municipality of Macuspana, Tabasco, is located at 17° 45′ 17′′ N, and 92° 33′ 32′′ W. The municipality is in the Grijalva-Usumacinta hydrological region (RH30), within the Grijalva Villahermosa basin (the most extensive state, represents 41% of the global surface) sub-basin of the Chilapa River. Its climate is warm humid, with abundant summer rains; It has a mean annual temperature of 23.6 °C, the maximum monthly average in April, with 30.1 °C and the minimum mean in May, with 29.8 °C; the absolute minimum and maximum reach 21.2 °C and 30.1 °C (INAFED, 2017).

The Macuspana area was surveyed, to assess the key actors and define the activities and document the opinions of the inhabitants. The tour survey covered the area occupied by the Bitzales rivers and the town of Jonuta, which borders the "Reserva de Los Pantanos de Centla" as well as the municipality of Macuspana. During these visits, the current state of the wells from "Pemex Exploración y Producción" was observed, identifying hydrocarbon stains in the water. Also, during the assessment, the conditions of the tenants and public services such as drainage, easily accessible drinking

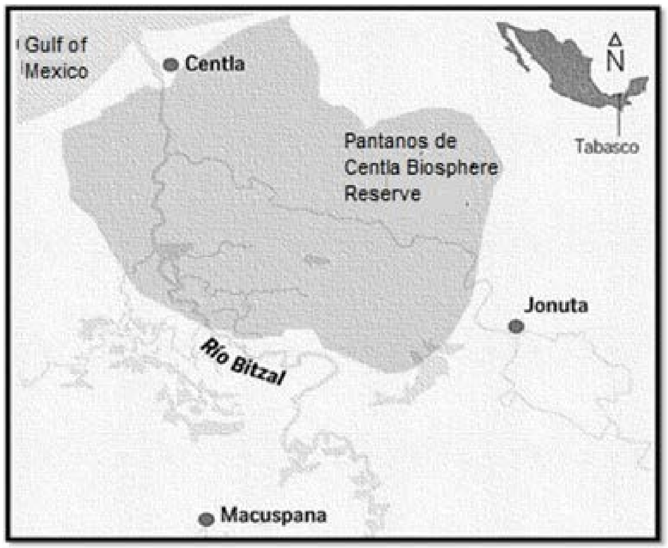

Figure 1. Location of the study area in the state of Tabasco, Mexico.

water and the exposure of people to contamination by hydrocarbons and heavy metals were analyzed. The prospecting assessment allowed to identify the main activity carried out by the inhabitants, such as fishing. It was also determined that most inhabitants have boats with internal combustion engines. This was an important factor to carry out the application of the survey and plan the strategy for its implementation.

Direct interviews

A survey was undertaken via direct face-to-face interviews with the tenants, fishermen and personnel who work at the Macuspana bodies of water; the survey theme was the contamination by hydrocarbons and heavy metals. In the assessment in Macuspana, a total of n=66 questionnaires were applied using key informants for the application of the questionnaires. A non-probabilistic chain sampling method was used to identify contamination, damage to public health, location of the wells, and impact of the presence of hydrocarbons.

The questionnaire was structured with open and closed questions, divided into different sections, such as general data, productive activity, resource management and the development in the tourism sector. To know and determine which are the activities with the greatest impact, public opinion and the knowledge they have about water pollution and management were surveyed.

In the productive activity section, 16 questions were asked, focused on the fishing activity to evaluate its infrastructure, the fishing volume and aspects of contamination of the lagoon. To gather information on fish mortality the presence of hydrocarbons and heavy metals was determined, as well as the opinion of the inhabitants and fishermen regard the oil sector. In the resource management section, 18 questions were asked focused on the type of species caught, capture frequency, location regarding the oil wells in the Macuspana lagoon and the type of maintenance that they observe on the wells.

The analysis information consisted of a qualitative and quantitative analysis using the statistic version 10 software, performing a frequency analysis and a Kruskal Wallis analysis of variance with ($p \leq 0.05$), and multivariate analysis with two factors.

RESULTS AND DISCUSSION

Among the main key actors involved in the hydrocarbon pollution phenomenon were: Pemex (Petróleos Mexicanos), Asea (Agency for security, energy and environment), Semarnat (Secretariat of the environment and natural resources), Conagua (National Water Commission), Government of Tabasco and the inhabitants of the municipality of Macuspana. Thirty-one percent of the surveyed families are made up of four people, 32% have a high school education, 78% of the families are engaged in fishing activities and are organized in fishing cooperatives. Twenty-five percent of fishermen obtain "mojarra" as their main product, followed by 12% of fishermen dedicated to capturing mojarra and shrimp (Figure 2). Regard the knowledge on the contamination by hydrocarbons and heavy metals, it was noted that more than 80% of people know about this issue (Figure 3A). This is because more than 75% of the people report having found dead fish as evidence of contamination in water bodies (Figure 3B).

Among the main cleaning treatments fish products are subjected to before consumption, 34% of the fishermen boiled and washed their product, and another 34% treated the products with lemon and chlorine. The main sources of contamination in Macuspana are contamination from oil activity, as more than 65% of those interviewed mentioned, it is due to the presence of oil wells and the activities related to carrying out the transport of catch fish with motorboats (Figures 4A; 4B).

They interviewed villagers mention that most of them have identified a total number of 38 oil wells located in the area, which generate a negative impact on the environment. The interviewees mention that they have

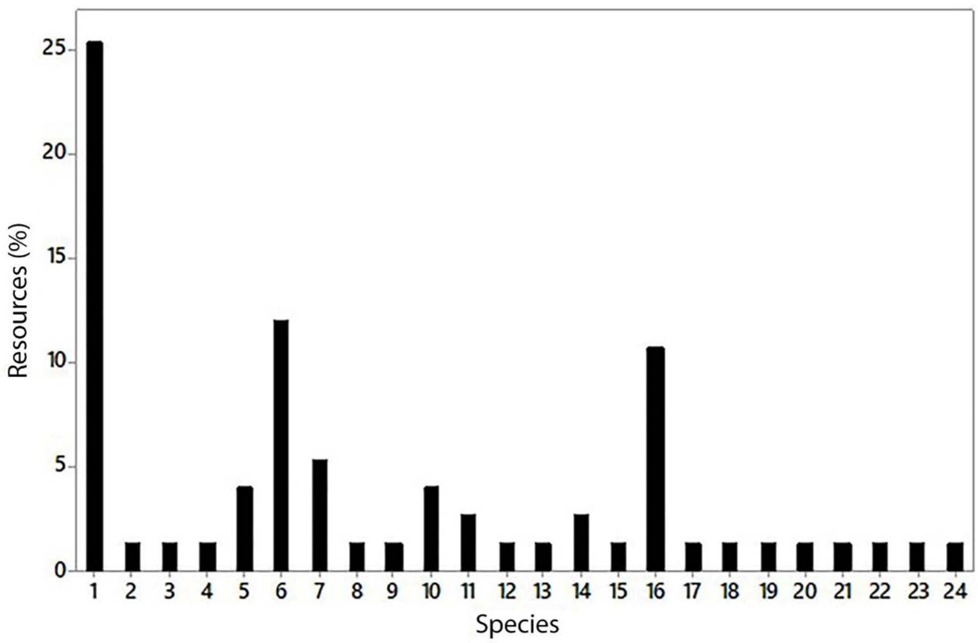

Figure 2. Main fishing resource that is extracted in the Macuspana lagoon, Tabasco. Mojarra (1), Carp-Tilapia (2), Common snook-Pejelagarto-Shrimp (3), Shrimp-Mojarra-Carp (4), Carp (5), Mojarra-Shrimp (6), Mojarra-Pejelagarto (7), Mojarra-Shrimp-Guabina (8), Carp-Mojarra-Shrimp (9), Tilapia (10), Tilapia-Shrimp (11), Common snook-Mojarra (12), Common snook-Mojarra-Pejelagarto (13), Carp-Mojarra (14), Mojarra-Corn (15), Shrimp (16), Mojarra-Common snook-Pejelagarto (17), No response (18), Mojarra-Carp-Hervíbora Carp (19), Common snook-Tilapia (20), Common snook (21) , Carp-Pejelagarto (22), Shrimp -Mojarra- Common snook (23), Mojarra-Pejelagarto-Shrimp (24).

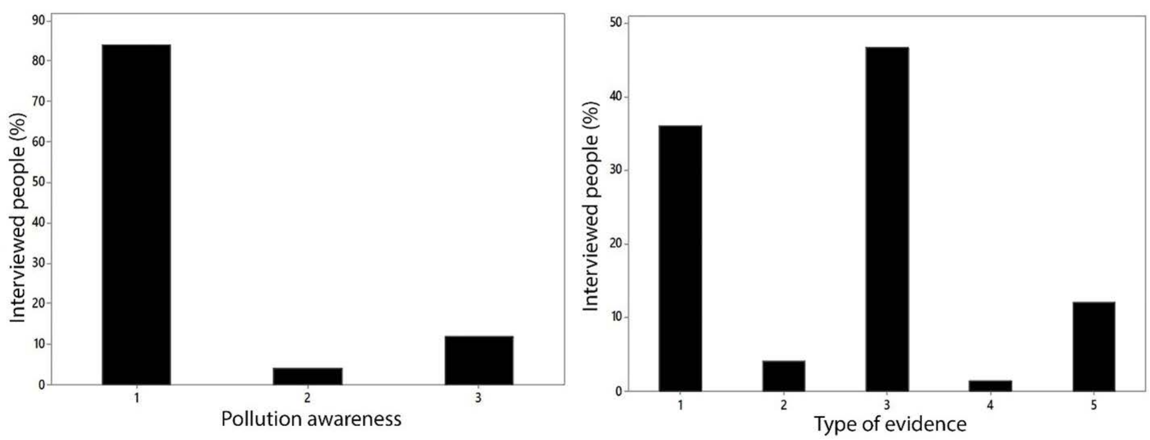

Figure 3. Left A). People's knowledge of the contamination by hydrocarbons and heavy metals. Yes (1), No (2) and They did not answer (3). Right B). Type of evidence of contamination. Death of fish (1), Effects on people (2), Death of fish and effects on people (3), Contamination of fish (4), They did not respond (5).

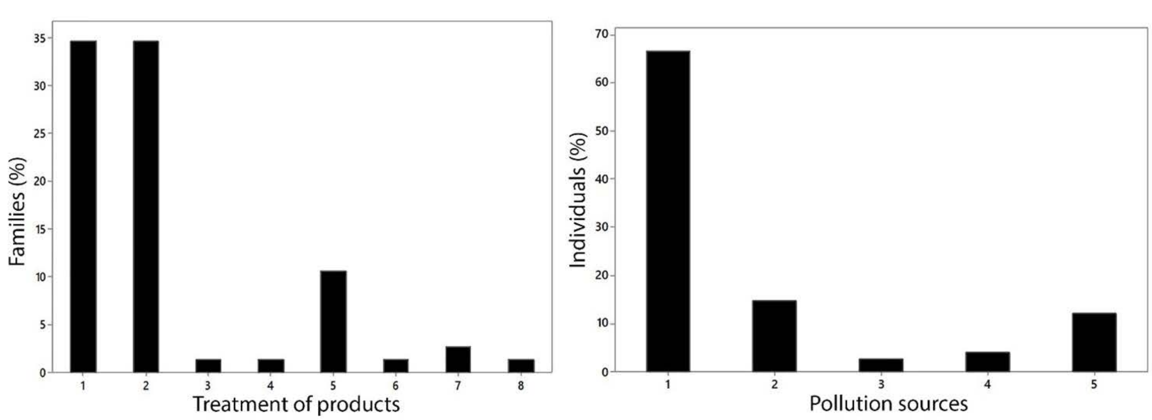

Figure 4. A). Treatment that is given to the products before consuming: Boiled-Wash (1), Wash (2), Lemon and chlorine wash (3), Wash with chlorinated water (4), Boil (5), Boil-Wash with chlorine (6), Washing with chlorinated water (7), No treatment (8). B). Source of contamination by hydrocarbons and heavy metals: Oil wells (1), Oil wells-Boats (2), Effluents (3), Oil wells-Effluents (4), They did not respond (5).

witnessed skin damages and gastrointestinal problems. Although, there is a small group that testifies having cancer problems, due to the presence of hydrocarbons and heavy metals in the water (Figure 5).

When comparing the years that fishermen have been exposed in the contaminated areas by hydrocarbons and heavy metals in Macupasna, significant statistical differences were identified between fishermen from the localities of Ejido San José, Tomo de la Bola and San Miguel; these were different from the localities of Emilio Narvaez, Criollo Narvaez, Bitzal 3 and Bitzal. Fishermen, 35 years on in the fishing activity in areas with the presence of oil wells and fishermen with a minimum of 20 years in the same areas were observed (Figure 6).

When relating all the contaminating variables with the productive activities in the Macuspana area, the multivariate analysis by two factors reports that there is a relation between the fishing destination, the volume of fishing and the affectation caused by the increase of oil in the area.

It was also observed that the interviewees have a relationship with the knowledge of fuel contamination and oil changes in boat engines, meaning that there is

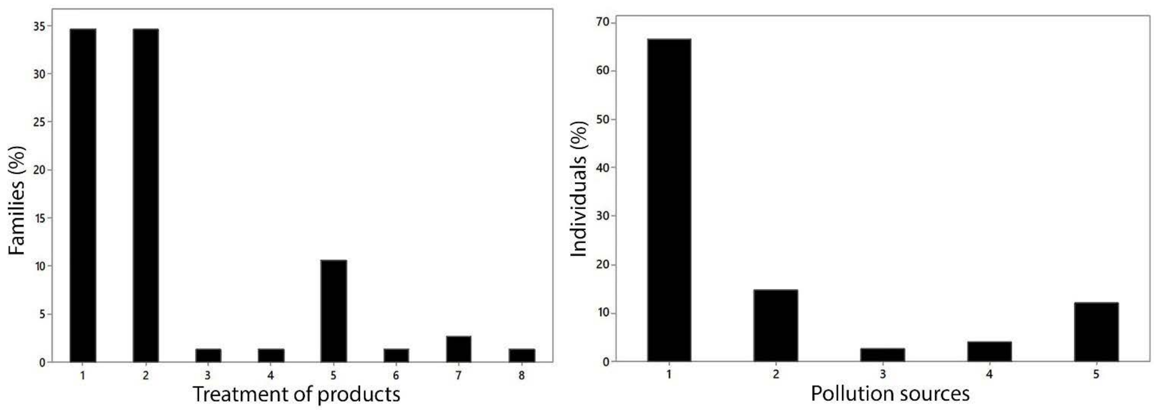

Figure 5. A). Number of oil wells in the Bitzal river area and in the Pantanos de Centla area, Tabasco: 0 (1), 3 (2), 4 (3), 5 (4), 6 (5), 8 (6), 10 (7), 15 (8), 16 (9), 20 (10), 25 (11), 30 (12), 23 (13), 33 (14), 34 (15), 35 (16), 36 (17), 37 (18), 38 (19), 40 (20), 50 (21), 60 (22), 90 (23), 100 (24), 200 (25). B). Types of health problems in the population of the towns of the municipality of Macuspana: Skin sores (1), Skin (2), Urticarias-Skin sores (3), Diarrhea (4), Diarrhea-Stomach (5), Skin -Stomach (6), Stomach (7), Itchy skin (8), Did not respond (9), Urticaria-Diarrhea (10), Gallbladder-Liver (11), Stomach-Vomiting (12), Skin sores- Diarrhea (13), Skin-Gastrointestinal (14), Urticaria-Vomiting (15), Liver Cancer (16), Kidney Cancer (17), Liver Cancer and Renal Insufficiency (18), Cancer (19), Urticaria (20) , Diarrhea-Vomiting (21), Skin spots (22), Skin allergies (23), Unanswered (24).

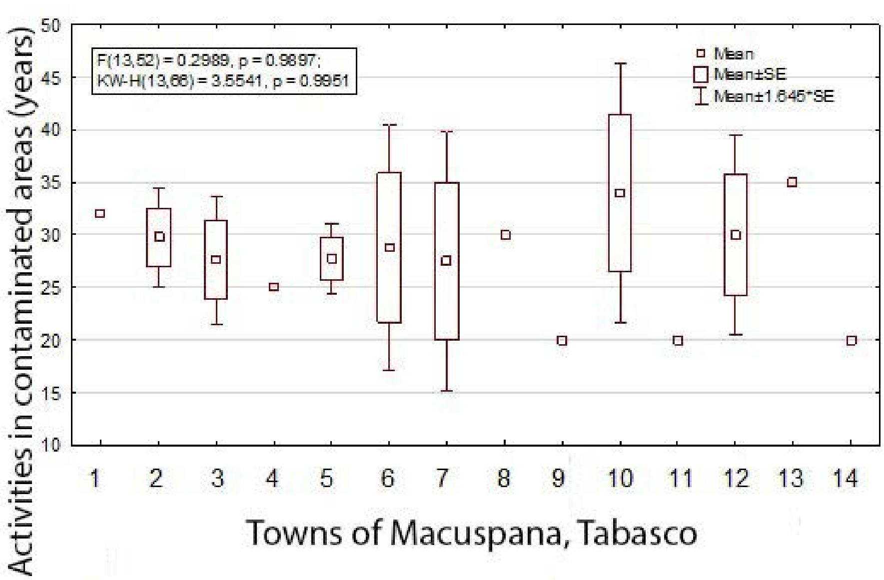

Figure 6. Years of fishing within areas contaminated with oil wells. Criollo Narváez (1), Ejido San José (2), Tomo de la bola (3), San Miguel (4), San José (5), Ejido el venadito (6), Bitzal 2 (7), Bitzal 4 (8), Emiliano Narvaez (9), Chichicaxtle (10), Criollo Narvaez (11), Ejido el Pibe Sanchez (12), Bitzal 3 (13), Bitzal 1 (14).

an impact due to poor management of boat systems for fishing activities in the area's bodies of water (Figure 7).

In Mexico there are soils contaminated by oil activity, due to the fact that hydrocarbons are obtained from activities such as exploration, refining, lack of maintenance and the theft of fuel are carried out. This panorama affects the social sphere, for example, a diagnosis carried out in the city of Puebla, showed that producers do not know preventive or reactive safety measures, and there is no organization for specialized care for exposure to hydrocarbons and other trace compounds such as heavy metals that are generated from oil activity (Cavazos *et al.*, 2014).

In Macuspana, given the pollution indicators, it was determined that the facilities and activities carried out by PEMEX are causing a significant impact in the localities and in the health sector; the lives of the inhabitants are at risk due to the release of sulfur and other toxins derived from sour gas production. It is important to note that the localities surrounding oil facilities are classified as marginalized due to the lack of public services (López *et al.*, 2019). PEMEX has several wells within the water bodies of the municipality of Tabasco, in operation and in recess, which represents a point source of hydrocarbon contamination. All pollutants are considered to be their final destination in the Gulf of Mexico; this impacts marine life and fishing activities due to the presence of pollutants. In the Corcovado Gulf in Chile, in sediment samples, the presence of aliphatic hydrocarbons from terrestrial plants was detected and in Quellón the presence of fuel derived from petroleum (Bonert *et al.*, 2010).

The deterioration in the quality of water and soils due to the exploitation of oil wells, uncontrolled spills and inadequate procedures in the handling of petroleum hydrocarbons, as well as the deterioration of pipes and ducts with the presence of corrosion, is the consequence of the lack of maintenance by the PEMEX company.

In the Mexican Republic, the distribution and location of oil pipelines and pipelines have been identified, it is necessary to monitor regulatory compliance for maintenance programs and prevent them from becoming sources of contamination (Orozco, 2010; Schmidt-Etkin, 2011). In this study, it was evidenced that there are pipes and wells in poor condition which negatively affect water bodies. Dead aquatic organisms such as crappies, carp and manatees were also recorded. Since the eighties, the activities of PEMEX in Tabasco have impacted the environment, the economy of the fishing social sector and the public health of the population; it has led, in general increase in diseases and politically affecting the inhabitants directly and indirectly (Pinkus and Contreras, 2012).

In the low alluvial plain of the state of Tabasco, in the oil district of Cinco Presidentes, 70 ng g^{-1} of polycyclic

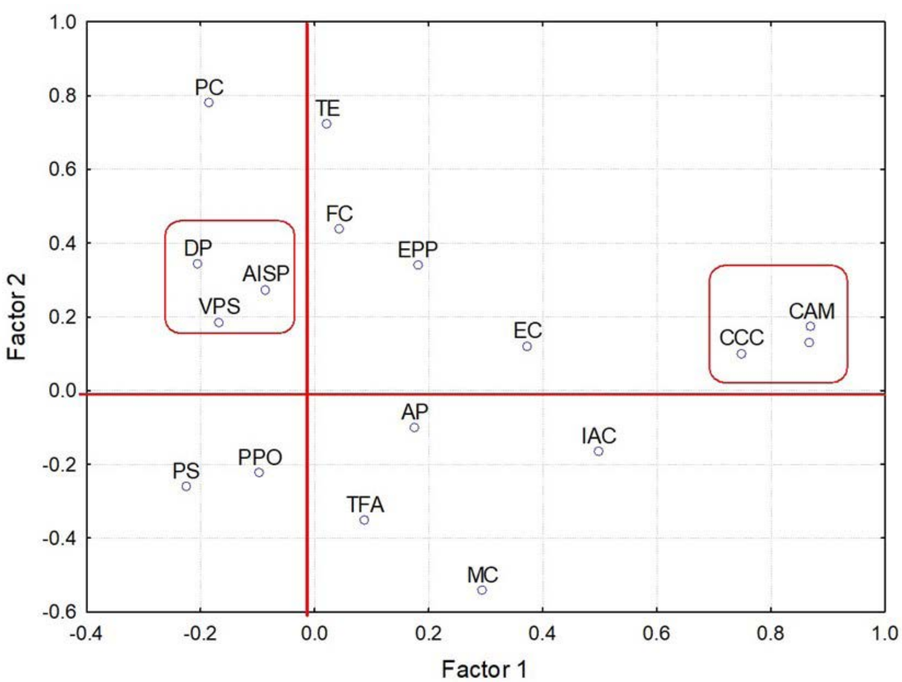

Figure 7. Multivariate analysis by two factors of the contamination of hydrocarbons and heavy metals, Knowledge of Fuel Contamination (CCC), Monthly Oil Change (CAM), Evidence of Contamination (EC), Time of Fish Production (EPP), Environmental Impact due to Fuel (IAC), Types of Diseases (TE), Sources of Pollution (FC), Years as a Fisherman (AP), Cancer Diseases (PC), Increase in the Oil Sector (AISP), Fishing Volume Weekly (VPS), Type of water source (TFA), Death from Cancer (MC), Fishing Destination (DP), Oil Wells in Operation (PPO), Health Problems (PS).

aromatic hydrocarbons were found in livestock land use, 45 ng g^{-1} were found in natural vegetation, and in the soil of a coconut production area was found 10 ng g^{-1} (Ortiz *et al.*, 2012). Despite the knowledge we have about contamination, it is necessary to initiate programs for the restoration of the affected areas or to implement measures of good hydrocarbon management. There is evidence in countries such as Venezuela on the impact of the management of wastewater from oil wells, in the State of Monagas, in savannah areas affected by the drilling and management of oil wells, it was found that wastewater management does not present an environmental risk due to the good drainage and precipitation of the sandy ultisol soils, which allowed the solubility of sodium (Na), in addition to the Na concentrations in wastewater treated with the coagulation and flocculation technique, decreased the levels of soluble aluminum in the soil, and high levels of Fe, Mn, Cu and Zn metals were not found (López *et al.*, 2020).

Implementing public policy options and bioremediation practices for hydrocarbons and heavy metals, with the use of microbial communities for their elimination from aquatic environments, as a strategy to solve this environmental problem (Alvares, 2015) is another alternative. The hypothesis that there is chronic pollution with risks to public health due to hydrocarbons and heavy metals that are generated from this activity is accepted, according to studies carried out on the water used and consumed by the inhabitants of Macuspana, Tabasco.

CONCLUSIONS

The oil sector has an impact on Macuspana, Tabasco, and towns such as Jonuta and Pantanos de Centla, considered the latter a biosphere reserve. It was observed that pollution problems in water bodies have existed for many years, and impact the aquatic life of endangered species, as well as species of commercial interest. The key actor's report and evidence damage to public health due to exposure to contamination by hydrocarbons and heavy metals.

REFERENCES

Acuña, A., Pucci, G., Morales, M. J., & Pucci, O. 2010. Biodegradación de petróleo y sus derivados por la comunidad bacteriana en un suelo de la Patagonia Argentina. Revista de la Sociedad Venezolana de Microbiología, 29-36.

Alvarez H. M., 2015. Biorremediación de ambientes contaminados con hidrocarburos: un proceso complejo que involucra múltiples variables. Revista químicaviva. 14(1):18-25.

Bonert C., Pinto L. Estrada R. 2010. Presencia de hidrocarburos en agua y sedimentos entre el Seno Reloncavi y el Golfo Corcovado (X Región)-CIMAR 10 Fiordos. Revista Ciencia y Tecnología del Mar. 33 (2). 89-94.

Bonert C., Pinto L., y Estrada R. 2006. Determinación de hidrocarburos en muestras de agua y sedimentos alrededor de la isla Robinson Crusoe. Ciencia y Tecnología del Mar. 29 (2):23-26.

Botello A.V. 2005. Características, composición y propiedades fisicoquímicas del petróleo, p. 261-268. *In*: A.V. Botello, J. Rendón-von Osten, G. Gold-Bouchot y C. Agraz-Hernández (Eds.). Golfo de México Contaminación e Impacto Ambiental: Diagnóstico y Tendencias, 2da Edición. Univ. Autón. De Campeche, Univ. Nal. Autón. de México, Instituto Nacional de Ecología. 696 p.

Cavazos A. J., Pérez A. B., Mauricio G. A. 2014. Afectaciones y consecuencias de los derrames de hidrocarburos en suelos agrícolas de Acatzingo, Puebla, México. Agricultura, sociedad y desarrollo. 11 (4): 539-550.

CNH (Comisión Nacional de Hidrocarburos). 2020. Tablero de producción de petróleo y gas. https://produccion.hidrocarburos.gob.mx/

Ferrera C. R., Rojas A. N. G., Poggi V. H. M., Alarcon A., Cañizares V. R. O., 2006. Procesos de biorremediación de suelo y agua contaminados por hidrocarburos del petróleo y otros compuestos orgánicos. Revista latinoamerica de microbiología. 48 (2): 179-187.

González P. (2009). Efecto de la fracción arcillosa y de la vermicomposta en la biodegradación de hidrocarburos, Tesis de maestría, posgrado en Biotecnología UAM.

Guzmán–Vera, E., Aranda–García, M., 2002, Inversión estructural, un nuevo concepto sobre la evolución de la Cuenca de Macuspana y sus implicaciones en la acumulación de hidrocarburos (resumen), en III Reunión Nacional de Ciencias de la Tierra, Puerto Vallarta, Jal.:Geos, 22(2), p. 214.

INEGI, 2011. Informe 2011 actividades y resultados. 406 p. https://www.inegi.org.mx/contenidos/transparencia/contenidos/doc/15_inf11.pdf

López H. D., Hernández C., Liendo F., Urich J., Vallejo T. O., 2020. Efectos de las aguas residuales de pozos petroleros sobre los suelos de sabanas ubicadas cerca de el furrial, Estado Monogas, Venezuelas. Rev. Int. Contam. Ambie. 36(3): 835-845. DOI: http://dx.doi.org/10.20937/RICA.53600.

López M. A. L., López M. S., López H. E. S., Ramos A. S. A., 2019. Impactos asociados a actividades petroleras en zonas aledañas al complejo procesador PEMEX gas-Macuspana. Journal of Basic Sciences, 5 (15): 109-123. https://doi.org/10.19136/jobs.a5n15.3572.

Murphy B. L., y Morrison R. D. 2002. Introduction to Environmental Forensics. California : Academic Press.

Orozco M. 2010. Selección de ecotipo de Bouteloua curtipendula con potencial fitorremediador y su evaluación frente a diferentes mezclas de hidrocarburos, Tesis de especialidad, posgrado en Biotecnología UAM.

Ortiz S. R., Cram S. Sommer I. 2012. Hidrocarburos aromáticos policiclicos (HAPS) en suelos de la llanura aluvial baja del estado de Tabasco, México. Universidad y ciencia trópico húmedo. 28(2): 131-144.

PEMEX 2020. Anuario estadístico del 22 de Noviembre de 2020. Obtenido de https://www.pemex.com/ri/Publicaciones/Anuario%20Estadistico%20Archivos/anuario-estadistico_2019.pdf

Pinkus Rendón, M. J., & Contreras Sánchez, A. 2012. Impacto socioambiental de la industria petrolera en Tabasco: el caso de la Chontalpa. Limina R, 122-144.

Reis J. C. 1996. Environmental control in petroleum engineering. Houston: Gulf Publishing Company.

Romay B. A. B., Pousa F. M.C. 2019. Influencia de los metales pesados e hidrocarburos en la calidad seminal. Revista Iberoamericana de Fertilidad y Reproducción Humana. 36(3): 3-8.

Santana R. J. L., Valdes C. M., Olivares R. S., & Lima C.L. 2012. Determinación de hidrocarburos aromáticos policíclicos ligeros en aguas superficiales de los ríos Almendares y Luyanó en La Habana. Revista CENIC. Ciencias químicas, 1-7.

Schmidt-Etkin D. 2011. Spill ocurrences: A world overview. En M. Fingas, Oil spill science and technology (págs. 7-48). Oxford: Gulf Professional Publishing.

https://doi.org/10.32854/agrop.v14i05.2050

N, P, K nutrition differentially affects the incidence and severity of the attack of pests and diseases in plants

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ABSTRACT

Objective: To document and analyze relevant results reported on the relationships kept by the essential elements, nitrogen (N), phosphorus (P), and potassium (K) with biotic stress factors in higher plants.

Design/methodology/approach: A bibliographic analysis was carried out using keywords related to the concepts of nutrient relationship with phytopathogens, plant fertilization and nutrition and biotic stress. Subsequently, the most relevant articles on N, P, and K and their relationship with pests and diseases were selected and analyzed.

Results: The elements N, P, and K affect the development of pests on plants. Fertilization with N tend to increase the presence of pests, while fertilization with P and K decreases it. However, this cannot be generalized for all crops or pests.

Limitations/implications of the study: Research on the effects of N, P, and K on the incidence of phytopathogens is limited and in most cases the mechanisms that determine such relashionship are not described.

Findings/conclusions: Fertilization with N causes a higher incidence of pests and diseases in plants, while fertilization with P and K can contribute to reduce their incidence. However, due to the great diversity of responses, these statements are not applicable to all cases and depend on other factors such as the crop and the pest present in the agroecosystem. It is required to carry out studies that make it possible to clarify exactly how these essential elements influence the development of diseases in different crops, and thus be able to make nutrition recommendations in which limiting biotic factors are taken into account.

Keywords: plant nutrition-phytopathogens relationship; fertilization; plant nutrients; biotic stress.

INTRODUCTION

Crop yield is affected by different stress factors, both of biotic and abiotic nature (Calanca, 2017). As sessile organisms, plants do not have the option to escape them and must develop resistance mechanisms and strategies to overcome their presence and attack (Gull *et al.*, 2019).

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Plants experience abiotic stress when the environmental conditions deviate from the optimal range for best growth and reproduction. Thus, for example, abiotic stress is stimulated by abnormal climatic conditions, such as temperatures that are too high or too low; persistent absence or excess of rain; high salinity, common in arid or semi-arid environments, where rainfall is too scarce to prevent the accumulation of ions in the soil and where irrigation is a secondary cause of salinization; excess or deficit of solar radiation; strong winds; and floods, among others (Calanca, 2017).

Biotic stress is caused by agents such as viruses, bacteria, fungi, nematodes, insects, arachnids, and weed species, which deprive the plant of nutrients or space and can cause its death (Gull *et al*., 2019). Yield losses from biotic stress factors are around 35%, and these could increase under the imminent imbalance within agroecosystems that climate change has brought with it (Baillo *et al*., 2019). Given the aforementioned, different strategies have been sought for pest control, among which we can cite: cultural, mechanical, chemical, and biological methods, among others (Frank *et al*., 2018). For much of recent history, the method of choice for farmers to control pests has been the use of chemicals, due to its speed and low cost. However, this method has brought several consequences, including a reduction in biodiversity, a decrease in pollinating insect populations, as well as different effects on human health. Therefore, it is imperative to have an Integrated Pest Management (IPM) as a strategy to control populations of harmful organisms, which in turn reduces the negative impacts on the environment, economy, and public health. The IPM involves the use of various management methods, from prevention to evaluation of the implemented measures (Steiro *et al*., 2020).

The proper management of plant nutrition is a fundamental component for the success of a crop, and its correct implementation can decrease the negative impact of several biotic stress factors on crop growth, development, and productivity indicators. However, the proper integration of nutritional aspects with the IPM turns out to be a real challenge, since numerous factors intervene in this relationship, such as the environment, the genetics of the plant, and the pest in question (Feller *et al*., 2018).

In fact, the nutritional status of a plant can negatively or positively affect the severity of a pest attack. Thus, resistance or susceptibility of the plant to a disease, morphological and histological structures and properties, synthesis of defense compounds, and virulence and survival capacity of the pathogen are components that can be affected by plant nutrients; and the responses that have been recorded in different crops are diverse. A plant with nutritional deficiencies is less vigorous and more susceptible to attack by pests (Singh, 2015). However, the adequate supply of some nutrients can increase the severity of the attack of some pathogens (Veresoglou *et al*., 2013).

Therefore, the objective of this review was to document the relevant results reported about the relationships between nitrogen (N), phosphorus (P), and potassium (K), essential elements in higher plants, and biotic stress factors.

NITROGEN

Nitrogen (N) is an essential element, determining factor for the growth and development of plants (Alcántar *et al*., 2016). Its concentration in plant tissues ranges from 1.5 to 2.0% on a dry base. This element is required for the synthesis of different molecules and macromolecules such as amino acids, proteins, nucleotides, coenzymes, and chlorophyll (Singh, 2015). Of the total proteins in plants, N represents about 16% (Sun *et al*., 2020). The assimilation of N is related to key physiological processes such as photosynthesis, photorespiration, respiration, and the tricarboxylic acid cycle, among others (Sun *et al*., 2020).

Interaction of N with pests

In general, it has been established that N fertilization increases the incidence of pests and diseases in plants. N increases succulent tissues, the concentration of amino acids in the apoplast, and improves the canopy of plants, in addition to delaying maturity (Singh, 2015). All these factors favor the incidence of pests (Sun *et al*., 2020).

Excess N can increase the incidence of biotrophic pathogens and have the opposite effect for necrotrophic ones (Sun *et al*., 2020). The application of high doses of N aggravates diseases caused by obligate pathogens, while mitigating those caused by facultative pathogens (Singh, 2015).

In addition to dose, the form of N, or the ratio of ammonium (NH_4^+) to nitrate (NO_3^-), has an effect on diseases. The severity of diseases such as take-all (caused by the fungus *Gaeumannomyces graminis* var. *tritici*) increases with the application of NO_3^- and decreases with the supply of NH_4^+. The effect can also be the inverse, for example, in cases of blackleg (bacterial wilt caused by the Gram-negative bacterium *Ralstonia solani*) and infections by various species of *Fusarium* (Singh, 2015; Sun *et al*., 2020).

On the other hand, N deficiency can influence the dispersion of virulence factors such as type III secretion systems (T3SSs) in bacterial pathogens or promote the accumulation of amino acids such as gamma-aminobutyric acid (GABA) in the area of infection (Sun *et al*., 2020). GABA is a cell signaling molecule that prepares the plant for defense in the event of attacks by pathogens.

By applying high rates of nitrogen fertilization, there is a greater population of pests such as whiteflies, thrips, leafhoppers, and aphids. N is one of the most important factors in the development of herbivore populations. The application of nitrogen fertilizers tends to stimulate the preference of herbivores towards certain N-rich tissues, increases the supply of succulent tissues; and thus raising the survival, growth, reproduction, and population density of herbivores (Shah, 2017). A correct joint application of K and N, keeping an adequate ratio between both, can be beneficial and prevent the development of insect pests (Bala *et al*., 2018).

Role of nitrogen in the defense mechanisms of plants

N is a key element in the construction of the defense system of plants. For example, this nutrient negatively affects the physical defenses, since when there is an excess of N fertilization, there is an increase in plant growth, but at the cost of the formation of lignin and the waxy cuticle, which makes the plants more susceptible to penetration by pathogens and insects. It can also negatively affect the synthesis of phytoalexins, secondary metabolites that can limit infection by pathogens. In some cases, NO_3^- nutrition can increase the production of secondary metabolites such as phenols and flavonoids, and have positive effects on antimicrobial proteins. Increasing the supply of N can also generate greater enzymatic activity of chitinases and pathogenesis-related proteins (PRs). N also participates in the regulation of enzymes such as phenylalanine ammonium lyase (PAL), which catalyzes the synthesis of defense metabolites against pathogens such as t-cinnamic acid and p-coumaric acid. N also stimulates the activity of antioxidant systems in plants, which reduces damage to the cell membrane (Sun *et al*., 2020).

PHOSPHORUS

Phosphorus (P) is a nutrient with vital functions for plant growth and productivity. Its concentration in plant tissues ranges between 0.05% and 0.5% of the total dry weight of the plant. Although the P concentration in the soil is 2000 times higher than in the plant, its fixation in the form of aluminum/iron or calcium/magnesium phosphates makes it unavailable for absorption by plants. Therefore, plants frequently face problems of P deficiency in agricultural fields (Malhotra *et al*., 2018).

P is decisive in the metabolism of plants, as it is responsible for the formation of adenosine triphosphate (ATP) and phospholipids in the membranes. Furthermore, it plays a key role in the formation of sugar phosphates and several vital nucleotides and coenzymes in plants. It is important for energy transfer, cell division, proper growth, and yield (Singh, 2015).

Interaction of P with pests

The effect of P on the incidence or severity of diseases is not consistent and depends on the crop and the pathogen in question. Proper P fertilization effectively reduces the severity and incidence of soil-borne diseases, such as *Pythium* root rot in wheat or common potato scab caused by *Streptomyces* spp. P also reduces diseases such as downy mildew, blue mold, blight, and tobacco leaf curl virus (TLCV) (Singh, 2015).

Phytophagous insects show a much higher P content than their host plants, which causes a mismatch that imposes limitations inherent to meeting the nutritional requirements of these pest organisms. When fertilizing with P, there may be positive and negative effects on the incidence and growth of insect pests (Bala *et al*., 2018). In cases of sucking insects such as aphids and leafhoppers, higher P levels are associated with a higher incidence of insects (Shah, 2017; Bala *et al*., 2018). For the leafminer *Liriomyza trifolii*, P also has a significant deterrent effect at high concentrations, decreasing the incidence of the insect pests (Facknath and Lalljee, 2005).

Role of phosphorus in the defense mechanisms of plants

In potatoes, P can reduce the incidence of pests through the synthesis of different secondary metabolites such as phenols and terpenes. Phenolic compunds can interfere with the digestion, growth, enzyme activity, and cell division processes of insect pests. Furthermore, terpenes interfere with neuronal activity and block phosphorylation in insects. P participates in the accumulation of lignins and tannins that act as barriers that deter different pests (Bala *et al*., 2018). Inorganic phosphate (Pi) deficiency induces the jasmonic acid (JA) pathway, thus improving plant defenses against insects (Khan *et al*., 2016).

POTASSIUM

Potassium (K) is involved in a long list of cellular processes. Unlike other important macronutrients, K is not incorporated into organic matter, but remains as a soluble ion in cell sap, contributing up to 10% of dry organic matter (Ragel *et al*., 2019). It acts as an activator of different enzymes, in addition to playing a very important role in protein synthesis, stomatal opening and closing, photosynthate translocation, and root growth (Singh, 2015). Consequently, it is an essential element for plants that affects a series of physiological and biochemical processes that are involved in their resistance to biotic and abiotic stress factors (Wang *et al*., 2013).

Interaction of K with pests

The negative effects caused by phytophages and phytopathogens in plants decrease with K fertilization (Amtmann *et al*., 2008). However, sometimes effects are not observed, or even K fertilization can be beneficial for the pest (Wang *et al*., 2013). In general, K contributes to improving the defense responses of plants to attacks by fungi and insect pests. Contrastingly, K fertilization does not show significant effects against diseases caused by bacteria and viruses (Davis *et al*., 2018). For some diseases, K can interact negatively with other elements such as Ca, causing an increase in diseases where Ca intervenes in the biology of the zoospore, such as collar rot and citrus gummosis (caused by the oomycete *Phytophthora parasitica*) (von Broembsen *et al*., 1997; Singh, 2015). For arthropods, K fertilization has a negative effect on the development of populations of sternorrhynchans (aphids and leafhoppers), orthopterans, and coleopterans, while the effect is positive for the development of mites and lepidopterans (Shah, 2017; Bala *et al*., 2018).

Role of potassium in plant defense

The optimal supply of K plays an important role in the development of diseases. In most plants with insufficient K, higher amounts of sugars and amino acids are generated and exuded, which favors the presence of diseases. Furthermore, K deficiency significantly decreases the production of antifungal compounds at the site of infection (Singh, 2015).

Low levels of K induce the synthesis of reactive oxygen species (ROS) and phytohormones such as auxins, ethylene, and jasmonic acid (JA), which causes greater tolerance to stress induced by both biotic and abiotic stress factors (Wang *et al*., 2013). Strengthening the defense system of the plant can be achieved by supplying sufficient levels of K in the early growth stage and then decreasing this supply when reaching the terminal stage (Shabala and Pottosin, 2014).

CONCLUSION

The nutritional status of the plant is decisive in the activation of defense mechanisms against biotic stress factors. In the present work, various roles that the essential elements N, P, and K play against pest organisms and causal agents of plant diseases were analyzed. In general, it is considered that overfertilization with N causes a higher incidence of pests and diseases in plants, while adequate fertilization with P and K results in their reduction. However, these statements are not applicable to all cases and depend on other factors such as the crop and the pest or pathogen present. Due to this variation in responses, more studies are needed to clarify exactly how these nutrients influence the development of pests in different crops, and thus be able to make plant nutrition formulas that take into account limiting biotic factors.

REFERENCES

Alcántar, G.G., Trejo-Téllez, L., & Gómez-Merino, F. C. (2016). Nutrición de Cultivos (2da ed.). Montecillo, México: Colegio de Postgraduados.

Amtmann, A., Troufflard, S., & Armengaud, P. (2008). The effect of potassium nutrition on pest and disease resistance in plants. Physiologia Plantarum, 133(4), 682–691. Doi: 10.1111/j.1399-3054.2008.01075.x

Baillo, E. H., Kimotho, R. N., Zhang, Z., & Xu, P. (2019). Transcription factors associated with abiotic and biotic stress tolerance and their potential for crops improvement. Genes, 10(10), 771. Doi: 10.3390/genes10100771

Bala, K., Sood, A. K., Singh, V., & Thakur, S. (2018). Effect of plant nutrition in insect pest management: A review. Journal of Pharmacognosy and Phytochemistry, 7(4), 2737–2742.

Calanca, P.P. (2017). Effects of abiotic stress in crop production. In M. Ahmed, C. Stockle (Eds.), Quantification of Climate Variability, Adaptation and Mitigation for Agricultural Sustainability (pp. 1-21). Cham, Switzerland: Springer.

Davis, J. L., Armengaud, P., Larson, T. R., Graham, I. A., White, P. J., Newton, A. C., & Amtmann, A. (2018). Contrasting nutrient-disease relationships: Potassium gradients in barley leaves have opposite effects on two fungal pathogens with different sensitivities to jasmonic acid. Plant, Cell & Environment, 41(10), 2357–2372. Doi: 10.1111/pce.13350

Facknath, S., & Lalljee, B. (2005), Effect of soil-applied complex fertiliser on an insect–host plant relationship: *Liriomyza trifolii* on *Solanum tuberosum*. Entomologia Experimentalis et Applicata, 115: 67-77. Doi: 10.1111/j.1570-7458.2005.00288.x

Feller, U., Kopriva, S., & Vassileva, V. (2018) Plant nutrient dynamics in stressful environments: Needs interfere with burdens. Agriculture, 8(7), 1-6. Doi: 10.3390/agriculture8070097

Frank, S., Bradley, L. K., & Moore, K. A. (2018). Integrated pest management. North Carolina Extension Gardener Handbook. NC State Extension, Raleigh, NC. [Accessed: 26-03-2021]. Retrieved from: http://content.ces.ncsu.edu/8-integrated-pest-management-ipm

Gull, A., Lone, A. A., & Wani, N. U. I. (2019). Biotic and Abiotic Stresses in Plants. In A. B. De Oliveira (Ed.), Abiotic and Biotic Stress in Plants (pp. 1-6). London, United Kingdom: IntechOpen. Doi: 10.5772/intechopen.85832

Khan, G. A., Vogiatzaki, E., Glauser, G., & Poirier, Y. (2016). Phosphate deficiency induces the jasmonate pathway and enhances resistance to insect herbivory. Plant Physiology, 171(1), 632-644. Doi: 10.1104/pp.16.00278

Malhotra, H., Vandana, Sharma, S., & Pandey, R. (2018). Phosphorus nutrition: Plant growth in response to deficiency and excess. In M. Hasanuzzaman, M. Fujita, H. Oku, K. Nahar, B. Hawrylak-Nowak (Eds.), Plant Nutrients and Abiotic Stress Tolerance (pp. 171-190). Singapore: Springer. Doi: 10.1007/978-981-10-9044-8_7

Ragel, P., Raddatz, N., Leidi, E.O., Quintero, F.J. & Pardo, J.M. (2019). Regulation of K+ Nutrition in Plants. Frontiers in Plant Science, 10(281), Doi: 10.3389/fpls.2019.00281

Shabala, S., & Pottosin, I. (2014). Regulation of potassium transport in plants under hostile conditions: implications for abiotic and biotic stress tolerance. Physiologia Plantarum, 151(3), 257-279. Doi: 10.1111/ppl.12165

Shah, T. H. (2017). Plant nutrients and insects development. International Journal of Entomology Research, 2(6), 54-57.

Singh, D. P. (2015). Plant nutrition in the management of plant diseases with particular reference to wheat. In: L.P. Awasthi (Ed.), Recent Advances in the Diagnosis and Management of Plant Diseases (pp. 273-284). New Delhi, India: Springer. Doi: 10.1007/978-81-322-2571-3_20

Steiro, Å. L., Kvakkestad, V., Breland, T. A., & Vatn, A. (2020). Integrated pest management adoption by grain farmers in Norway: A novel index method. Crop Protection, 135, 105201. Doi: 10.1016/j.cropro.2020.105201

Sun, Y., Wang, M., Mur, L. A. J., Shen, Q., & Guo, S. (2020). Unravelling the roles of nitrogen nutrition in plant disease defences. International Journal of Molecular Sciences, 21(2), 572. Doi: 10.3390/ijms21020572

Veresoglou, S. D., Barto, E. K., Menexes, G., & Rilling, M. C. (2013). Fertilization affects severity of disease caused by fungal plant pathogens. Plant Pathology, 62(5): 961-969. Doi: 10.1111/ppa.12014

von Broembsen, S. L., & Deacon, J. W. (1997). Calcium Interference with zoospore biology and infectivity of *Phytophthora parasitica* in nutrient irrigation solutions. Phytopathology, 87(5), 522-528. Doi: 10.1094/PHYTO.1997.87.5.522

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. International Journal of Molecular Sciences, 14(4), 7370-7390. Doi: 10.3390/ijms14047370