Endocarp morphology as an aid for discriminating wild and cultivated Mexican hawthorn (*Crataegus mexicana* Moc and Sessé)

R Nieto-Angel
Departamento de Fitotecnia
Universidad Autónoma Chapingo
56230 Chapingo Méx
Mexico

J Ortiz
F Gonzalez-Andres
Departamento de Biología Vegetal
ETS Ingenieros Agrónomos
Universidad Politécnica de Madrid
28040 Madrid
Spain

MW Borys
Agronomía-Recursos Naturales
Universidad Popular Autonoma del Edo de Puebla
21 Sur 1103
Col Santiago
72160 Puebla, Pue
Mexico

Endocarp morphology as an aid for discriminating wild and cultivated Mexican hawthorn.

ABSTRACT

INTRODUCTION. The genus *Crataegus* includes a high number of species, although a certain confusion exists, due to apomixis and polyploidy. A study of the endocarp from *Crataegus mexicana* Moc and Sessé was carried out in order to relate the domesticated or wild situation of the plants to their origin in Mexico. **MATERIALS AND METHODS**. External and internal parameters were evaluated with an image analyser, and the multivariate analysis of the results was carried out afterwards. **RESULTS AND DISCUSSION**. The obtained dendrogram grouped the accessions into two well defined groups. One of them included the domesticated material, from the Central plateau of Mexico (Puebla and Mexico states), mostly thornless and with edible fruits. The other was formed by the wild accessions, most of them from the state of Chiapas; they have thorns and characteristics related to rusticity, and were collected in mountainous areas. The principal component analysis showed that the three first components have a high cumulative variance (90.6%). The three-dimensional plot also showed the existence of the two mentioned groups. **CONCLUSION**. The obtained results evidence the utility of the endocarp morphology for characterization of the hawthorn.

KEYWORDS
Mexico, *Crataegus mexicana*, genetic resources, provenance, endocarp.

La morphologie de l'endocarpe peut aider à discriminer les *Crataegus mexicana* sauvages et cultivés.

RÉSUMÉ

INTRODUCTION. Le genre *Crataegus* comprend un grand nombre d'espèces, cependant, une certaine confusion existe du fait de l'existence d'apomixie et de polyploïdie. Une étude de l'endocarpe de *Crataegus mexicana* Moc et Sessé a été entreprise pour mettre en relation les formes domestiquées ou sauvages de cette plante avec l'origine de son installation au Mexique. **MATÉRIEL ET MÉTHODES**. Des paramètres externes et internes ont été évalués à l'aide d'un analyseur d'images, et les résultats ont été ensuite soumis à une analyse multivariable. **RÉSULTATS ET DISCUSSION**. Le dendrogrammme obtenu a scindé les accessions en deux groupes bien définis. L'un d'eux regroupe l'ensemble du matériel domestiqué provenant du plateau central du Mexique (États de Puebla et de Mexico) ; ses plants sont presque sans épines et fournissent des fruits comestibles. L'autre groupe est formé par les accessions sauvages, originaires, pour la plupart, de l'État de Chiapas. Ces plants portent des piquants et ils présentent des caractéristiques de rusticité ; ils ont été collectés en régions montagneuses. L'analyse en composantes principales a montré que les trois premiers axes avaient une forte variance cumulée (90,6 %). La représentation des résultats en trois dimensions a confirmé l'existence des deux groupes déjà mentionnés. **CONCLUSION**. Les résultats obtenus mettent en évidence l'utilité de la morphologie du péricarpe pour la caractérisation des *Crataegus mexicana*.

MOTS CLÉS
Mexique, *Crataegus mexicana*, ressources génétiques, provenance, endocarpe.

Received 11 March 1996
Accepted 23 July 1997

Fruits, 1997, vol 52, p 317-324

Resumen Spañol, p 324

introduction

The genus *Crataegus* includes a high number of species, although a certain confusion exists, due to apomixis and polyploidy (CRONQUIST, 1981; PHIPPS, 1983; NIETO-ANGEL et al, 1993).

LOUDON (1838) grouped the genus into 14 sections, each one having common characteristics. More recently, RUSANOV (1965) mentioned a total of 25 series that grouped the different species of the genus.

EL-GAZAAR (1980), based on the leaf morphology, geographical distribution and chromosome number, grouped the *Crataegus* in two different subgenera: *Crataegus* and *Americanae*. The subgenus *Crataegus* would include two related sections: *Oxyacanthae* and *Azaroli*. According to the mentioned author, all the Eurasian species belong to the section *Oxyacanthae* or section *Azaroli*. The subgenus *Americanae* would include the rest of species, being a rather heterogeneous group. PHIPPS (1983) indicates that not all the Eurasian species belong to the sections *Oxyacanthae* and *Azaroli*. Moreover, PHIPPS noted that EL-GAZAAR's division of *Crategus* into two subgenera on the basis of the chromosome number is false, because all *Crataegus* have a base number of x=17.

PHIPPS et al (1990) mentioned a total of 186 species within the genus *Crataegus*, 69 from Eurasia and 117 from America. They arranged them in 14 sections. The sections *Parvifoliae* Loud, *Cordalae* Beadle ex Egglest, *Virides* (Beadle ex Sarg) Schneider, *Microcarpae* Loud, *Lacrimatae* (Phipps) Phipps, *Aestivales* (Sarg) Schneider, *Brevispinae* Beadle ex Schneider, *Douglasii* Loud, *Crusgalli* Loud, *Coccinae* Loud only include American species. The sections *Sanguineae* Zabel ex Schneider, *Hupehensis* Phipps and *Cuneatae* Rehder ex Schneider only include Eurasian species. The section *Crataegus* (=*Oxyacanthae* Loud) was arranged in five series. One of them, *Apiifoliae* (Loud) Rehder, only has the American species *Crataegus marshallii* Egglest. The other four only include Eurasian species. These series are *Crataegus* (=*Oxyacanthae* (Loud) Rehder), *Pentagynae* (Schneider) Rus, *Azaroli* (Loud) Rehder and *Pinnatifidae* (Zabel ex Schneider) Rehder.

The section *Mexicanae* Loud included two series. The first one is *Mexicanae* (Loud) Rehder and has three species: *C Mexicana* Moc and Sessé from Mexico and Guatemala, *C stipulosa* (HBK) Steud from Ecuador and Peru and *C nelsonii* Egglest from Mexico. The second one is *Henryanae* (Sarg) Phipps and has only one species: *C scabrifolia* (Franch) Rehder from Yunnan (SE China).

There is a theory (PHIPPS, 1983) that the scabrifolioid-mexicanoid stock crossed from Asia to North America through the Bering, early in the Tertiary or the Miocene and migrated to the South. This fact would explain the minor diversification of the mexicanoid stock.

The genus *Crataegus* is mostly situated between 30° to 50° N in latitude, although plants can be located outside these limits (PHIPPS, 1983). The Mexican *Crataegus* group expands throughout the highlands of Guatemala and Mexico, and apparently belongs to the species *C mexicana*. *C pubescens* (HBK) Steud non (C Presl) has been reported as a species that expands from North Guatemala to North Mexico, between approximately 13° and 40° N in latitude (PHIPPS, 1983; NIETO-ANGEL and BORYS, 1991a, b). According to some authors *C pubescens* and *C mexicana* are synonymous (PHIPPS, 1983; NIEMBRO-ROCAS, 1990; PHIPPS et al, 1990).

The *Crataegus* in Mexico presents a very high variability for different characteristics. The main interest of this genus is as an horticultural plant, either used as a rootstock, as an interstock or as a cultivar. Also the value as forage, medicinal, ornamental or ecological should be mentioned (BORYS, 1989; PAYNE et al, 1990; BORYS and LESZCYŃSKA-BORYS, 1990; NIETO-ANGEL and BORYS, 1993a, b).

The fruits were already used during the precolonial period. Since 1824, this genus has been commercially grown in different regions of Mexico. At present, most of the commercial plantations and backyard trees are located in the states of Mexico and Puebla, while wild plants are found in many mountain regions of the state of Chiapas.

Fruits are consumed either as fresh fruit or in marmalades, jellies or syrups. They are also used for extraction of pectin, preparation of beverages, or extraction of medicinal principles. In general, they have the same uses of the rest of the hawthorn species of China, North or South America (HIGAREDA, 1984; PAYNE et al, 1990).

The genus *Crataegus* has a wide range of adaptability to calcium in the soil. Also, a marked variation exists in the flowering period, tree productivity, fruit quality, and compatibility as a rootstock for pear, quince, apple or even hawthorn trees (CRUZ-SANPEDRO et al, 1984; NIETO-ANGEL et al, 1984; HERRERA-GONZÁLEZ et al 1987; MEJÍA-CALDERÓN et al, 1987; NIETO-ANGEL et al, 1987).

In the present work, 20 wild and domesticated accessions of *Crataegus* were studied in order to assess their variability based on the morphology of the endocarp, ie, the most convenient plant material to be stored at the germplasm banks.

A former list and preliminary evaluation of the accessions was carried out by NIETO-ANGEL and BORYS (1992), where the existing biodiversity of the plant material was evidenced, as a result of the measurements of fruiting shoots and leaf area.

material and methods

The plant material used for the present work (table I) was sampled from an arboretum located at the Chapingo University experimental plots (Mexico). All trees were grown under identical conditions, and were 8 years old at the time of the study. This plant material is a broad representation of the wild and cultivated *Crataegus mexicana* present in two zones of Mexico.

The cultivated or domesticated accessions are distributed in the central plateau of Mexico (Mexico State and Puebla), while the wild ones come from different locations of Chiapas, in the South of Mexico (table I); one wild accession from Puebla was included for comparison. No cultivated specimens from Chiapas have been detected.

From each accession, 25 well developed fruits were randomly selected, and the endocarp was separated and washed.

One piece of the endocarp from each fruit was used for the study. Measurements were carried out with parameters (table II; figure 1), whose selection was made according to the

Table I
Characterization of the accessions of hawthorns studied for their endocarp morphology in Mexico.

Code	*Accession number at the Chapingo germplasm bank*	*State where germplasm was originally collected*	*Type*	*Thorns*
1	G5	Chiapas	Wild	No
2	G25	Chiapas	Wild	Yes
3	G28	Mexico State	Cultivated	No
4	G40	Mexico State	Cultivated	No
5	G48	Puebla	Cultivated	No
6	G51	Mexico State	Cultivated	No
7	H2A4	Chiapas	Wild	Yes
8	H2A17	Chiapas	Wild	Yes
9	H2A20	Chiapas	Wild	Yes
10	H2A31	Chiapas	Wild	Yes
11	H3A5	Chiapas	Wild	Yes
12	H3A9	Chiapas	Wild	Yes
13	H3A12	Chiapas	Wild	Yes
14	H3A24	Chiapas	Wild	Yes
15	H4A35	Chiapas	Wild	Yes
16	H5A33	Chiapas	Wild	Yes
17	H9A41	Chiapas	Wild	Yes
18	G45	Mexico State	Cultivated	Yes
19	G27	Chiapas	Wild	Yes
20	G32	Puebla	Wild	Yes

Table II
Endocarp characteristics measured for discriminating wild and cultivated Mexican hawthorn.

Hawthorn endocarp character	*Abbreviation*
Lateral view of the endocarp:	
maximum length (mm)	L
Cross section of the endocarp:	
Lower angle (°)	α
Longest lobe length (mm)	LLL
Shortest interlobe length (mm)	SIL
Outer perimeter (mm)	OP
Cross section total area (mm^2)	CSTA
Cross section total area (form factor [1])	CSTA ff
Inner perimeter (mm)	IP
Seed hole area (mm^2)	SHA
Seed hole area (form factor [1])	SHA ff
Number of lobes	NL
Percent of endocarps with seed hole	% hole
Percent of endocarps with seed	% seed

[1] Form factor = $(4\pi \text{ area/perimeter})^2$

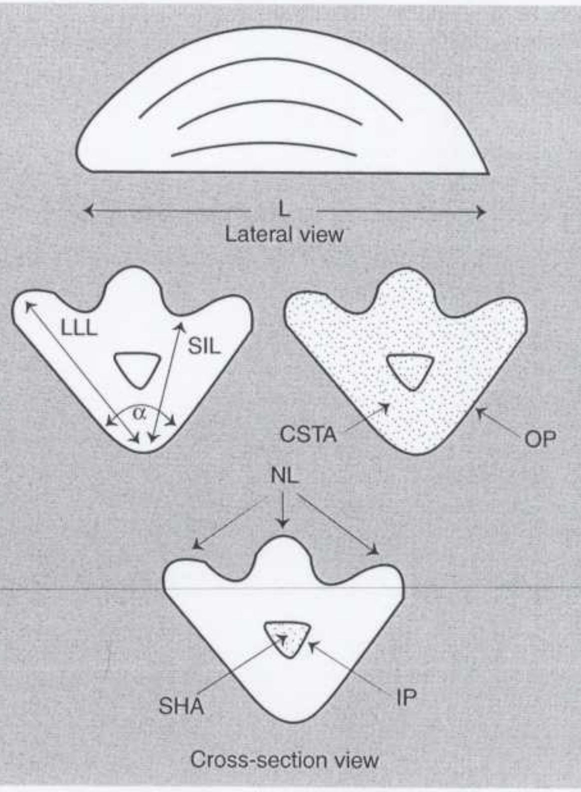

Figure 1
Endocarp characteristics measured for discriminating wild and cultivated Mexican hawthorns. Abbreviations given in table II.

characteristics of the endocarp, trying to evaluate the maximum of non-related measurable characters.

Treatment of the results was carried out with the NTSYS computer program (ROHLF, 1990). The data matrix was standardised, and the similarity matrix was calculated with the distance coefficient. A cluster analysis was carried out with the UPGMA (unweighted pair-group method, arithmetic, average). In addition, PCA (principal components analysis) was used for the three-dimensional representation.

results and discussion

The external parameters maximum length (L) and outer perimeter (OP) reached maximum values for the accessions '3', '4', '5', '6' and '18', that correspond to the domesticated *Crataegus mexicana* (table III).

The evaluation of the fruiting shoots for some genotypes from Chiapas, Puebla or Mexico (NIETO-ANGEL and BORYS, 1992) showed that the wild genotypes had shorter shoots and less foliar surface than the domesticated ones. Hence, a correlation between growth of the shoots and size of the endocarp exists.

The internal parameters measured–; the total area of the cross section (CSTA), the inner perimeter (IP) and the area of the seed hole (SHA)– reached also the highest values for the same accessions.

In a previous study (PÉREZ-MARTÍNEZ et al, 1984), the percentages of endocarp with seed reached values lower than 40% (less than 20% in most cases) for the varieties from Chiapas, up to values higher than 55%, even up to 96%, for the varieties from Puebla or Mexico State. These values roughly correspond to the results obtained in the present study (table III).

The percentage of holes and the percentage of seeds (table III) reached, in most of the cases, similar values, which indicates that most of the holes have the corresponding seed inside. Exceptions to this are the accessions with codes '9', '10', '12', '13', '14' and '15', where less than 75% of the holes have seed.

Table III
Average values of the measured characters according to table II and figure 1. Code numbers correspond to table I. Numbers in italic are the standard deviations.

Code	L (mm)		α (°)		LLL (mm)		SIL (mm)		OP (mm)		CSTA (mm²)		CSTA form factor	
1	6.43	*0.16*	89.63	*7.37*	4.83	*0.16*	3.97	*0.25*	13.23	*0.45*	11.33	*0.80*	0.78	*0.01*
2	6.13	*0.16*	88.17	*4.93*	4.28	*0.16*	3.62	*0.16*	10.43	*0.27*	7.07	*0.38*	0.80	*0.00*
3	9.70	*0.30*	101.62	*6.13*	6.01	*0.30*	5.25	*0.32*	15.46	*0.45*	15.98	*0.85*	0.82	*0.00*
4	9.61	*0.22*	89.60	*5.36*	6.24	*0.11*	5.48	*0.16*	15.26	*0.38*	15.68	*0.72*	0.83	*0.01*
5	9.92	*0.20*	95.99	*4.14*	5.79	*0.22*	5.04	*0.28*	14.96	*0.48*	14.85	*0.98*	0.82	*0.00*
6	10.60	*0.22*	79.79	*4.48*	7.04	*0.24*	6.30	*0.30*	16.09	*0.51*	17.60	*1.01*	0.84	*0.01*
7	7.92	*0.15*	77.90	*4.32*	5.74	*0.13*	5.00	*0.18*	13.88	*0.30*	12.32	*0.53*	0.79	*0.00*
8	6.48	*0.12*	71.47	*3.41*	5.05	*0.14*	4.45	*0.23*	11.97	*0.26*	9.38	*0.47*	0.80	*0.01*
9	6.86	*0.19*	83.73	*5.99*	4.74	*0.19*	4.11	*0.18*	12.37	*0.27*	9.86	*0.46*	0.79	*0.00*
10	6.63	*0.27*	86.89	*5.45*	4.93	*0.14*	4.47	*0.11*	13.05	*0.38*	10.69	*0.58*	0.77	*0.01*
11	7.27	*0.17*	82.81	*2.87*	5.58	*0.15*	5.03	*0.19*	14.33	*0.36*	13.06	*0.66*	0.78	*0.00*
12	7.46	*0.20*	83.59	*3.73*	5.35	*0.17*	4.43	*0.17*	13.85	*0.34*	12.60	*0.59*	0.81	*0.00*
13	6.43	*0.16*	82.12	*3.27*	5.05	*0.15*	4.63	*0.14*	11.23	*0.28*	8.15	*0.42*	0.79	*0.00*
14	6.91	*0.10*	77.72	*2.83*	5.06	*0.18*	4.45	*0.14*	12.10	*0.30*	9.60	*0.47*	0.81	*0.00*
15	6.99	*0.16*	71.98	*4.78*	4.97	*0.13*	4.42	*0.18*	12.39	*0.29*	9.99	*0.44*	0.79	*0.01*
16	6.85	*0.19*	83.51	*4.64*	5.27	*0.12*	4.52	*0.10*	12.52	*0.42*	10.31	*0.67*	0.81	*0.01*
17	6.67	*0.17*	62.77	*5.09*	4.82	*0.16*	4.30	*0.23*	11.17	*0.31*	7.83	*0.41*	0.77	*0.01*
18	8.29	*0.19*	87.85	*5.08*	5.63	*0.12*	4.86	*0.18*	14.81	*0.47*	15.04	*0.86*	0.84	*0.00*
19	6.95	*0.14*	84.13	*4.80*	5.25	*0.23*	4.58	*0.24*	12.38	*0.36*	9.63	*0.62*	0.76	*0.01*
20	7.91	*0.21*	86.48	*6.03*	4.58	*0.16*	4.26	*0.35*	13.50	*0.35*	12.27	*0.70*	0.84	*0.01*

Table III continued

Code	IP (mm)		SHA (mm²)		SHA form factor		NLL		% hole	% seed
1	4.17	*0.24*	0.89	*0.17*	0.46	*0.06*	2.80	*0.24*	42	42
2	2.99	*0.35*	0.75	*0.16*	0.56	*0.06*	3.30	*0.21*	44	40
3	5.93	*0.20*	2.01	*0.20*	0.65	*0.05*	2.50	*0.26*	83	75
4	6.11	*0.17*	2.22	*0.19*	0.69	*0.04*	2.90	*0.10*	88	80
5	5.58	*0.24*	1.94	*0.21*	0.66	*0.05*	2.50	*0.22*	76	72
6	6.03	*0.29*	2.16	*0.21*	0.63	*0.04*	2.80	*0.20*	84	64
7	3.54	*0.35*	0.76	*0.20*	0.40	*0.06*	2.30	*0.15*	32	32
8	3.36	*0.36*	0.73	*0.18*	0.44	*0.60*	2.40	*0.22*	36	36
9	2.91	*0.34*	0.63	*0.17*	0.46	*0.05*	3.00	*0.14*	36	16
10	3.96	*0.32*	0.87	*0.17*	0.46	*0.06*	2.50	*0.30*	56	40
11	3.91	*0.41*	0.87	*0.19*	0.45	*0.05*	2.40	*0.16*	44	40
12	3.53	*0.40*	0.88	*0.21*	0.49	*0.05*	2.70	*0.15*	39	22
13	2.55	*0.30*	0.42	*0.14*	0.41	*0.05*	2.70	*0.21*	24	16
14	3.17	*0.35*	0.73	*0.18*	0.48	*0.06*	2.70	*0.26*	36	20
15	3.59	*0.39*	0.97	*0.18*	0.58	*0.05*	2.60	*0.26*	52	28
16	3.82	*0.45*	1.23	*0.21*	0.71	*0.04*	3.40	*0.16*	61	56
17	2.70	*0.38*	0.69	*0.16*	0.58	*0.05*	2.20	*0.13*	36	32
18	6.09	*0.28*	2.31	*0.17*	0.73	*0.03*	2.60	*0.16*	96	88
19	1.63	*0.22*	0.12	*0.07*	0.38	*0.04*	2.50	*0.16*	4	4
20	5.02	*0.38*	1.65	*0.20*	0.82	*0.07*	3.08	*0.21*	92	92

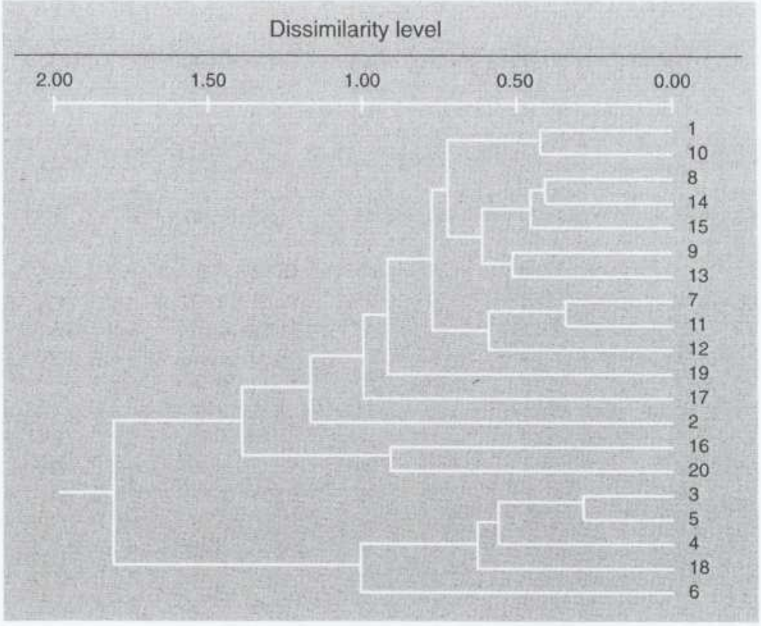

Figure 2
Dendrogram obtained after cluster analysis of results from hawthorn endocarp measurements.

According to the results obtained, the low percentage of germination of the wild hawthorns, that has been frequently mentioned in the Southern area, is probably due to the absence of seed rather than to a low viability.

The dendrogram of figure 2 shows the formation of two main groups, that are separated at a dissimilarity level of 1.8. One of them includes the domesticated species '3', '4', '5', '6' and '18', and the other one the 15 remaining wild species.

The results of the PCA show that the three first components account for a cumulative variance of 90.6% (table IV).

Character eigenvector values along the first three factors are summarised in table V. The three attributes responsible for maximum separation along the first component are the seed hole area (SHA), the inner perimeter (IP), and the cross-section total area (CSTA). Along the second component, note the number of lobes (NL), and, along the third component, the lower angle (α).

In figure 3, which represents the three-dimensional plot for the three first components of the PCA, again two main groups are visible, which confirms the previously mentioned grouping. One of them includes the accessions with code numbers '3', '4', '5', '6' and '18' (domesticated specimens), and the other the wild ones. Within the first group, number '6' is rather separated from the others.

The correspondence of both analysis supports the existence of the two groups, one with all the wild *Crataegus*, and the other with the domesticated selections.

Table IV
Eigenvalue percentages and cumulative variance obtained in the principal component analysis carried out with the results of hawthorn endocarp measurements.

Component	*Eigenvalue*	*% variance*	*Cumulative variance*
First	8.62	66.3	66.3
Second	2.29	17.6	83.9
Third	0.88	6.8	90.6
Fourth	0.63	4.9	95.5
Fifth	0.19	1.4	96.9
Sixth	0.16	1.3	98.2
Seventh	0.11	0.8	99.0
Eighth	0.06	0.4	99.4
Nineth	0.03	0.3	99.7
Tenth	0.03	0.2	99.9
Eleventh	0.00	0.0	>100
Twelveth	0.00	0.0	
Thirteenth	0.00	0.0	

conclusion

The results of the present work show that the endocarp is discriminant for characterization of the *Crataegus* sp. This part of the fruit has the advantage of being stable and easy to store. It can be concluded that the analysed accessions are clearly grouped according to their cultivated or wild condition.

references

Borys MW (1989) Valor ecológico del tejocote (*Crataegus* spp). In: *Memorias del I Congreso de Ecología "La Era Ecologíca"*. Puebla, Pue, México, 11-24

Borys MW, Leszcyñska-Borys H (1990) Tejocote planta de solares, de maceta y de interiores. In: *II Congreso Nacional de Horticultura Ornamental*. Puebla, Pue, México, p 23.

Cronquist A (1981) An integrated system of classification of flowering plants. New York, USA, Columbia Univ Press

Cruz-San-Pedro EA, Nieto-Angel R, Borys MW (1984) Comportamiento de plántulas de tejocote (*Crataegus pubescens* HBK) a los suelos calcáreos. *Chapingo* (México) 45/46, 206-207

El-Gazaar A (1980) The taxonomic significance of leaf morphology in *Crataegus* (Rosaceae). *Bot Jahrb Syst* 101, 457-469

Herrera-Gonzalez MJ, Nieto-Angel R, Borys MW (1987) Siete cultivares de pera (*Pyrus domestica* Med) injertados en tejocote (*Crataegus pubescens* HBK). *Chapingo* (México) 56/57, 111-116

Higareda A (1984) Industrialización integral del tejocote. México, DF, México. Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, tesis de licenciatura

Loudon JC (1838) Arboretum et Fruticetum Brittanicum. London, Royaume-Uni

Mejia-Calderon O, Nieto-Angel R, Serrano-Covarrubias LM, Borys MW (1987) Injertos de cultivares de manzano (*Malus domestica*), pera (*Pyrus domestica*) y membrillero (*Cydonia oblonga*) injertados en tejocote (*Crataegus pubescens* HBK) de tres procedencias. *Chapingo* (México) 56/57, 87-93

Niembro-Rocas A (1990) Arboles y arbustos útiles de México. Naturales e introducidos. Chapingo, México, Universidad Autónoma de Chapingo, Limusa Noriega

Nieto-Angel R, Borys MW (1991a) El Tejocote (*Crataegus* spp) en México. In: *Avances en el Estudio de los Recursos Fitogenéticos de México.* Chapingo, Méx, México, Ortega-P R, Palomino-H G, Castillo-G F, Gonzalez-H VA, Livera-M M (Eds), Somefi (Soc Mex de Fitogenética), 309-324

Nieto-Angel R, Borys MW (1991b) Tejocote, agente ecológico. *La Trilla* (México) 19, 16-18

Nieto-Angel R, Borys MW (1992) Banco de Germoplasma de Tejocote (*Crataegus* spp) de la República mexicana. *Chapingo* (México) 77, 126-130

Nieto-Angel R, Borys MW (1993a) El tejocote (*Crataegus* spp); un potencial frutícola para la producción de zonas templadas y frías. *Fruticultura Profesional* (España) 54, 64-71

Nieto-Angel R, Borys MW (1993b). El tejocote (*Crataegus* spp) como portainjerto de árboles frutales: relaciones fisiológicas. *Fruticultura Profesional* (España) 56, 29-37

Nieto-Angel R, Borys MW, Barrera-Guerra JL (1984) Segundo año de comportamiento vegetativo de cuatro cultivares de manzano (*Malus domestica*) injertados en tejocote (*Crataegus pubescens* HBK). *Chapingo* (México) 45/46, 89-92

Table V
Eigenvector values on the first three axes of the principal component analysis carried out with the results of hawthorn endocarp measurements. Character codes are explained in table II.

Character	*1st component*	*2nd component*	*3rd component*
L	0.92	-0.28	0.03
α	0.53	0.22	0.79
LLL	0.76	-0.58	0.00
SIL	0.74	-0.58	-0.09
OP	0.89	-0.34	0.16
CSTA	0.93	-0.29	0.13
CSTA ff	0.83	0.32	-0.15
IP	0.97	0.08	-0.01
SHA	0.98	0.14	-0.10
SHA ff	0.73	0.57	-0.29
NL	0.10	0.77	0.24
% hole	0.91	0.33	-0.14
% seed	0.87	0.36	-0.11

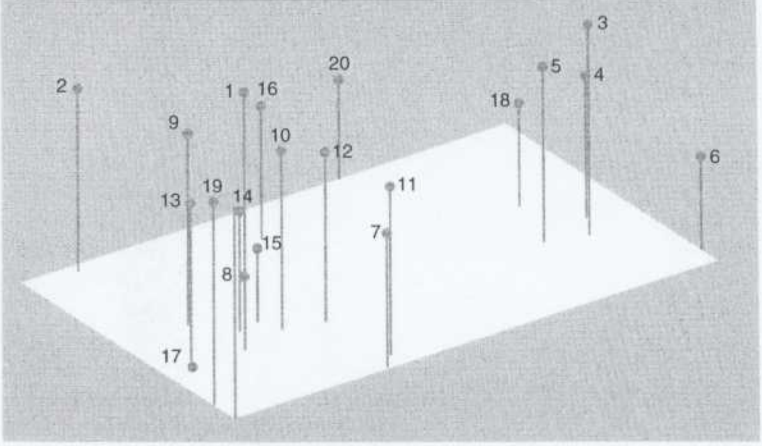

Figure 3
Three-dimensional diagram obtained from the principal component analysis carried out with the hawthorn endocarp measurements.

Nieto-Angel R, Borys MW, Barrera-Guerra JL, Pimienta-Barrios E, Zarate-De-Lara G (1987) Compatibilidad vegetativa de manzano (*Malus pumila* Mill) injertados en tejocote (*Crataegus pubescens* HBK). *Chapingo* (México) 56/57, 104-110

Nieto-Angel R, Sanchez-Chavez E, Borys MW (1993) Biología floral del *Crataegus* spp en México – Estudio preliminar. In: *Actas del II Congreso Ibérico de Ciencias Hortícolas.* Zaragoza, España, 360-365

Payne JA, Krewer GW, Fitenmiller RR (1990) Mayhaws: trees of pomological and ornamental interest. *HortScience* 25(3), 246, 375

Pérez-Martínez A, Nieto-Angel R, Borys MW (1984) Germinación de semillas y crecimiento de plántulas de tejocote (*Crataegus pubescens* HBK) de diferentes procedencias. *Chapingo* (México) 45/46, 185-188

Phipps JB (1983) Biogeographic, taxonomic, and cladistic relationships between East Asiatic and North American *Crataegus*. *Ann Missouri Bot Gard* 70, 667-700

Phipps JB, Roberston KR, Smith PG, Rohrer JR (1990) A checklist of the subfamily Maloideae (Rosaceae). *Can J Bot* 68 (10), 2209-2269

Rohlf FJ (1990) NTSYS-pc numerical taxonomy and multivariate analysis. Exeter software. New York

Rusanov FN (1965) Introdutsironavye boyaritschniki botanicheskogo sada an UzSSR. In: *Dendrologie Uzbekistanii*. (In Russian)

La morfología del endocarpio es útil para la caracterización de las accesiones de tejocotes silvestres y domesticados.

RESUMEN

INTRODUCCIÓN. Se llevó a cabo un estudio del endocarpio de *Crataegus mexicana* Moc & Sessé, con objeto de relacionar el origen del material con la domesticación de la especie en México. **MATERIAL Y MÉTODOS**. Se evaluaron los parámetros externos e internos del endocarpio con la ayuda de un analizador de imagen, realizando posteriormente un análisis multivariante de los resultados. **RESULTADOS Y DISCUSIÓN**. El dendrograma obtenido agrupó las accesiones en dos grupos bien definidos: el primero está constituído por el material domesticado, procedente de la meseta central de México (estados de Puebla y México). En él se incluyen las accesiones objeto de utilización agronómica, generalmente sin espinas y con frutos que son utilizados para el consumo humano. El segundo grupo, más numeroso, está integrado por las accesiones silvestres, la mayor parte de ellas procedentes del estado de Chiapas, que fueron recolectadas en zonas montañosas, siendo plantas silvestres, con presencia de espinas y con características que indican su rusticidad. El análisis de los componentes principales muestra que los primeros tres componentes tienen una alta variación acumulada (90.6 %). La representación tridimensional también muestra la existencia de los dos grupos antes mencionados. **CONCLUSIÓN**. Los resultados obtenidos ponen de manifiesto la utilidad de la morfología del endocarpio para la caracterización del tejocote.

PALABRAS CLAVES

México, *Crataegus mexicana*, recursos genéticos, procedencia, endocarpio.