Article

Morphological and productive characterization of accessions of non-toxic *Jatropha curcas* L. in the central region of Veracruz

Florencia García-Alonso[1]
Eliseo García-Pérez[2]
Arturo Pérez-Vázquez[2]
Ricardo Martínez-Martínez[3]
Lorena Casanova-Pérez[1§]

[1]Technological University of the Huasteca Hidalguense. Huejutla Chalahuiyapa highway s/n, Tepoxteco neighborhood, Huejutla, Hidalgo, México. Tel. 789 8962089. (florencia.garcia@uthh.edu.mx). [2]Postgraduate College-Veracruz *Campus*. Federal Highway Xalapa-Veracruz km 88.5, Veracruz, México. CP. 91690. AP. 421. (geliseo@colpos.mx; parturo@colpos.mx). [3]University of Guadalajara-University Center of the South Coast. National Independence Avenue 151, Downtown, Autlán de Navarro, Jalisco, Mexico. CP. 48900. (ricardo.mmartinez@academicos.udg.mx).

[§]Corresponding author: lorena.casanova@uthh.edu.mx.

Abstract

Jatropha curcas belongs to the family Euphorbiaceae, native to Mexico and Central America, currently grows in tropical and subtropical regions of the world. It is a multipurpose plant, whose interest in recent years is related to its potential as a raw material for biodiesel production. The objective of this research was to evaluate the morphological and productive characteristics of accessions of non-toxic *Jatropha curcas* L., collected in different regions of Veracruz and that were propagated by seed in the central region of the state in 2019. The plant material consisted of 23 accessions with five repetitions, plants that were three years old. The variables recorded were plant height, stem diameter, branches (primary, secondary, tertiary), leaf length and width, flower buds, number of clusters and fruits; length, width, color and number of seeds per fruit, in seeds the weight, length, width, thickness and total weight of seeds per plant were recorded. The analysis of variance detected significant differences ($p \leq 0.05$) between accessions for most variables. The principal component analysis, the first two explained 57.66% and 60.8% of the variation. In seed-propagated accessions, the outstanding variables were flower buds, clusters, fruits and seed production (accessions I-34, I-32 and I-47). These accessions have the greatest potential and vigor to be included in a genetic improvement program. It is concluded that there is a wide morphological variation in the accessions studied.

Keywords: morphological characterization, production, propagation.

Reception date: February 2023
Acceptance date: April 2023

Introduction

Jatropha is an oleaginous plant commonly known as physic nut, native to Tropical America, which belongs to the family Euphorbiaceae with approximately 188 species distributed mainly in tropical and subtropical regions of the world (Henning, 2004; Mabberley, 2005). It is a plant valued for its use in the production of biodiesel (Rajagopal, 2008). This species also has insecticidal and fungicidal properties (Nwosu and Okafor, 2007), is also used for food when it comes from non-toxic materials (Makkar *et al*., 2007) and for medicine when using the latex of its leaves (Mujemdar and Misar, 2004).

For that reason, species such as *J. curcas* require an agronomic characterization that allows knowing the constitution and functioning of its morphological components (Oliveira *et al*., 2009). This procedure describes the morphological, phenological and productive characteristics that distinguish one material from another within the same species (Valdés-Rodríguez *et al*., 2018). In recent years, this interest has already provided some findings regarding physiological, genetic, agronomic, agroecological and production characteristics of this species (Valdés-Rodríguez and Pérez-Vázquez, 2013; Zavala *et al*., 2016; Wencomo-Cárdenas *et al*., 2020).

Currently, works for the morphological characterization of *J. curcas* continue (Laviola, 2009), since the agronomic characteristics of *J. curcas* are diverse. This is due to its wide agroecological plasticity to develop under conditions of water stress (Trabucco *et al*., 2010; Pérez-Vázquez *et al*., 2013) and grow in infertile soils (Balota *et al*., 2011; Valdés-Rodríguez *et al*., 2020). Consequently, the objective of this research was to evaluate the morphological and productive characteristics of accessions of non-toxic *Jatropha curcas* L., located in the experimental field of the Veracruz *Campus* of the Colegio de Postgraduados.

Materials and methods

Study area. We worked with *J. curcas* plants from the Germplasm Bank of the Veracruz *Campus* of the Colegio de Postgraduados. The temperature data were obtained from the meteorological station of the institution and correspond to the year 2019. The climate of type Aw (w) (i') g, which corresponds to warm subhumid with rains in summer, an average annual rainfall of 1 100 mm and with an average temperature of 26 °C and a temperature fluctuation of 5-7 °C, with 5% rainfall in winter (García, 1988). In the evaluation period, a maximum temperature of 36 °C during April and a minimum of 14 °C in January were recorded, with a rainfall of 206 mm in September. In the rainy season, a rainfall of 28 mm was recorded.

Vegetative material. We worked with 23 accessions of *J. curcas*, three years old, collected in the state of Veracruz. Fruits and vegetative material were collected in 2019, and from this the germplasm bank was established in 2020. The seeds were sown in polyethylene bags and transplanted into the field in March 2020. The experiment was established in 2020 under a randomized complete block design and 23 accessions per seed were established, with five replications. Table 1 shows the origin and geographical location of the accessions collected.

Table 1. Origin and geographical location of the 23 accessions of non-toxic *J. curcas* evaluated, from the germplasm bank of the Veracruz *Campus*.

Accessions	Locality	Region	N Latitude	W Longitude	Altitude (m)
I-04	Santa Mónica	Huasteca Alta	21°18’ 32.8”	98°20’ 29.3”	130
I-05	Tepatlán Grande	Huasteca Alta	21°18’ 20.9”	98°16’ 30.0”	94
I-08	Tzicuatitla	Huasteca Baja	21°11’ 50.8”	97°59’ 18.9”	228
I-11	Zacamixtle	Huasteca Baja	21°14’ 55.3”	97°43’ 27.6”	136
I-13	Papantla	Totonaca	20°27’ 28.9”	97°19’ 16.2”	173
I-14	Papantla	Totonaca	20°27’ 26.8”	97°19’ 11.6”	170
I-18	Insurgentes Socialistas	Totonaca	20°11’ 25.5”	97°15’ 53.4”	119
I-22	Totomoxtle	Totonaca	20°28’ 01.0”	97°15’ 19.0”	43
I-25	Costa Esmeralda	Totonaca	20°15’ 22.8”	96°48’ 00.6”	5
I-26A	Cementeres	Nautla	20°10’ 38.9”	96°53’ 37.0”	9
I-26B	Cementeres	Nautla	20°10’ 38.9”	96°53’ 37.0”	9
I-27	Progreso	Nautla	20°06’ 57.0”	96°00’ 51.1”	70
I-30	Reforma Km 9	Nautla	19°53’ 19.6”	96°48’ 33.8”	631
I-31	Yecuautla	Nautla	19°50’ 35.0”	96°48’ 29.1”	1 054
I-32	Tuzamapan	Capital	19°24’ 00.7”	96°52’ 05.9”	892
I-34	Alvarado	Papaloapan	18°47’ 26.1”	95°45’ 31.7”	22
I-41	Revolución de Abajo	Tuxtlas	18°38’ 53.9”	95°06’ 50.0”	8
I-47	El Chichón	Olmecas	17°45’ 10.2”	94°06’ 32.6”	50
I-48	Acalapa II	Olmecas	17°57’ 47.1”	94°13’ 58.7”	42
I-62	Cuautlapan	Montañas	18°53’ 05.4”	97°01’ 02.0”	1 006
I-64	Tepetates	Sotavento	19°11’ 39.7”	96°20’ 38.0”	16
I-77	Pueblillo	Totonaca	20°15’ 15.0”	97°15’ 48.0”	78
I-80	Buenos Aires	Nautla	19°56’ 09.0”	95°50’ 00.0”	321

Soil analysis. A soil sampling was carried out in the germplasm bank, in a zigzag pattern at two depths (0-20 cm and 20-40 cm), which were sent to the water-soil and plant laboratory of the Colegio de Postgraduates, Veracruz *Campus*.

Morphological variables evaluated. The descriptors used were those indicated by Laviola (2009) and the *Jatropha* spp. Network (SAGARPA-SNICS 2014). The variables recorded were: plant height (PlH), measured from the base to the apex of the plant; stem diameter (SD) with a vernier at 10 cm from the ground; leaf length and width (LL and LW), the middle part of the leaf blade was measured; number of primary, secondary and tertiary branches (NB1, NB2, NB3), flower buds (NFB), clusters (NCL) and fruits (NF) per plant, length (FL), width (FW), shape (FS) of fruit and fruit color (FC) according to the Munsell table, seeds (NSF) per fruit.

The beginning of the recording of morphological variables began between May-October, performing a weekly sampling. In relation to the harvest of fruits, these were monitored every three days to obtain greater precision regarding the production of fruits per tree. The fruit harvest was carried out from May to October 2019, the seeds were extracted and dried at room temperature.

Production of seeds (PRS) per plant. The seeds were extracted manually and a sample of 30 seeds was taken randomly, for which the length (SL), width (SWi), thickness (ST) and weight (SWe) were determined. Statistical analysis. The data obtained were recorded in a spreadsheet of Excel Version 2010® and the analysis was performed using the program SAS (Statistical Analysis System) v. 9.4, an Anova and a Tukey mean test ($p \leq 0.05$) were carried out.

A principal component (PC) analysis was performed with all variables, and a correlation matrix using the Princomp procedure of SAS. The graphical representation of the principal components (PC1) and (PC2) aimed to identify similarities and differences between the accessions. Subsequently, a cluster analysis was carried out by means of the Euclidean distance and the clustering method of Unweighted Pair Group Method with Arithmetic Mean (UPGMA), with the statistical package Ntsys® (Rohlf, 2009).

Results and discussion

Morphological characterization

The analysis of variance detected statistically significant differences between accessions in 10 of the 20 morphological descriptors evaluated, particularly for the variables plant height ($p= 0.0001$), leaf width ($p= 0.0018$), flower buds ($p= 0.0001$), clusters ($p= 0.0001$), fruits ($p= 0.0001$), number of seeds per fruit ($p= 0.0001$), seed weight ($p= 0.0001$), seed length ($p= 0.0001$), seed width ($p= 0.0001$) and seed production ($p= 0.0001$). According to the Tukey mean test ($p \leq 0.05$), the maximum values in plant height were: 3.13 m and 3 m in accessions I-77, I-13 and I-26B. Manurung (2007) mentions that *J. curcas* is able to reach between 3 and 5 m and even up to 6 m in height in full development, so there are differences between accessions of the same age. Accession I-77 showed the highest number of flower buds with 264.

The maximum value of clusters was for accession I-34 with 181.60. Accessions I-32 and I-34 stood out with the highest number of fruits per plant with 558 and 531. These results are higher than those reported by Machado and Suárez (2009), who indicate that an African provenance had 455 fruits 240 days after being established in the field. Machado (2011) reports 102 fruits for a one-year-old provenance from Cape Verde; Srivastava *et al*. (2011) report 210 fruits in three-year-old plants propagated by seed. Accession I-25 stood out in the number of seeds per fruit with an average of 2.8, a normal number of seeds per fruit, which coincides with what was reported by Basha and Sujatha (2007).

In seed characterization, accession I-22 stood out in weight with an average of 0.84 g, accession I-62 in length with 20.13 mm and accession I-34 with 11.01 mm in width. These values coincide with what was reported by Martínez *et al*. (2010) and Valdés *et al*. (2013), who mention an average weight of 0.84 g, 17.41 mm in length, and 11.45 mm in seed width. In production of seeds per plant, accessions I-34 and I-32 stood out with 754.1 and 667.6 g respectively.

These results are superior to those of Sosa-Segura *et al*. (2012), who reported 30 to 36 fruits per plant, in germplasm from Puebla and Morelos, a seed production of 39 to 50 g in one-year-old plants. These data, even though they are not comparable due to the age differences of the plants, are a reference on the productive behavior of *J. curcas*. Guerrero *et al*. (2011) mention that the morphological and productive characteristics of greatest interest are: seed length, seed width, ratio of length and width of seed, number of seeds per fruit, seed weight, number of fruits per cluster and number of branches per plant. The parameters obtained in the present morphological characterization are shown in Table 2.

Table 2. Morphological characteristics of 23 accessions of *J. curcas*, sown in the central region of the state of Veracruz.

ACC	PlH (m)	LW (cm)	NFB	NC	NF	NSF	SWe (g)	SL (mm)	SWi (mm)	PRS (g)
I-04	2.53±0.3ab	14.44±0.7ab	167.6±41.7ab	101.4±34.2ab	368.4±124.1ab	2.47±0.1ab	0.68±0.02ab	18.61±0.2cd	9.94±0.2de	247.6±65.4dc
I-05	1.68±0.9ab	15.29±0.5ab	57.5±6.4ab	37.5±16.3ab	118.5±6.4ab	2.31±0.3ab	0.74±0.03bc	19.22±0.4ab	10.05±0.1cd	91.7±58.8dc
I-08	2.6±0.4ab	13.7±0.8ab	197±68.7ab	91±32.6ab	304.8±102ab	1.97±0.3ab	0.69±0.04f	17.99±0.2 cd	9.77±0.4e	173.3±79.8dc
I-11	2.2±0.3ab	15.78±1a	55.67±18.3ab	64±69.4ab	990±47.3ab	2.04±0.5ab	0.7±0.07de	18.14±0.8de	9.72±0.1e	51.3±47.9d
I-13	3±0.3a	13.34±0.6b	163.2±33.6ab	134.6±35.4ab	382.2±92.2ab	2.28±0.1ab	0.72±0.02cd	18.04±0.2cd	10.14±0.1bc	291±77.6bc
I-14	2.54±0.2ab	13.22±0.7b	138.8±41.4ab	56.4±24.3ab	150±57.1ab	2.22±0.2ab	0.81±0.04ab	19.07±0.5bc	10.17±0.2bc	147.2±79.8dc
I-18	2.68±0.2ab	14.65±0.5ab	110.6±11.3ab	76.80±7.9ab	251.6±42.3ab	2.4±0.1ab	0.77±0.02ab	18.82±0.3cd	10.31±0.2bc	240.3±149.4dc
I-22	1.99±0.5ab	14.76±0.9ab	46±1ab	39.5±50.2ab	142.5±188.8ab	2.08±0ab	0.84±0a	19.82±0ab	10.61±0ab	183.5±0dc
I-25	2.61±0.4ab	15.19±0.7ab	172.2±38.5ab	133±57.3ab	407.8±223.1ab	2.80±0a	0.74±0.02bc	18.47±0.2cd	10.1±0.2cd	374.3±191.1cd
I-27	2.63±0.2ab	14.96±1.0ab	167.8±55.0ab	110.6±48.4ab	383.2±146.4ab	2.56±0.1ab	0.73±0.02bc	18.53±0.4cd	10.33±0.5bc	276.3±84.9dc
I-30	2.86±0.2ab	15.17±0.9ab	154±33.7ab	104.8±55.7ab	233.6±78ab	2.65±0.2ab	0.77±0.02ab	18.27±0.2de	10.61±0.2ab	257.2±56.6dc
I-31	2.74±0.1ab	14.48±0.9ab	185.4±21.4ab	68.2±22.1ab	190.2±43.9ab	2.45±0.1ab	0.72±0.04cd	18.09±0.3de	10±0.3cd	70.8±19.8d
I-32	2.81±0.3ab	14.97±1.3ab	225.40±51.6 ab	162.00±25.9 ab	558.40±122.1 a	2.64±0.1ab	0.78±0.03 ab	18.56±0.4 cd	10.77±0.2 ab	667.6±50.7 ab
I-34	2.89±0.2ab	15.43±1.0ab	198.8±62.4ab	181.60±58.1a	530.6±248ab	2.53±0.1ab	0.79±0.03ab	18.53±0.4cd	11.01±0.1a	754.1±398.2a
I-41	2.91±0.1ab	14.67±0.9ab	191.2±47.2ab	95.6±49.3ab	371.4±219.3ab	2.42±0.2ab	0.76±0.01ab	18.31±0.5cd	10.56±0.1ab	361.2±191.1bc
I-47	2.74±0.2ab	15.34±1ab	153.2±45.5ab	111.6±29.1ab	434.4±126.8ab	2.48±0.2ab	0.79±0.03ab	18.92±0.4bc	10.19±0.1bc	465.3±156.4abc
I-48	2.6±0.2ab	14.73±1.2ab	128.25±34.4ab	99.25±6.8ab	396.75±84ab	2.43±0.1ab	0.78±0.03ab	18.63±0.5cd	10.19±0.5bc	286.5±62.2dc
I-62	2.5±0.2ab	14.38±0.8ab	144±50ab	88.8±18.5ab	377±101.4ab	2.5±0.2ab	0.81±0.05ab	20.13±0.2a	10.31±0.1bc	287.5±90.1dc

ACC	PlH (m)	LW (cm)	NFB	NC	NF	NSF	SWe (g)	SL (mm)	SWi (mm)	PRS (g)
I-64	2.58±0.2ab	14.62±0.6ab	121.67±29.8ab	96.67±16.8ab	347.33±88.9ab	2.63±0.2ab	0.73±0.02ab	18.2±0.1de	10.74±0.2ab	357.8±99.4bc
I-77	3.13±0.3a	15.48±0.2ab	246±38a	94±6.2ab	278.67±56.1ab	2.44±0.1ab	0.74±0.01bc	18.25±0de	10.22±0bc	239±27.8dc
I-80	2.87±0.4ab	14.63±0.8ab	167.8±89.9 ab	66.2±22ab	158.4±89.9ab	2.24±0.1cd	0.76±0.01ab	18.59±0.2 cd	10.07±0.2cd	125.1±55.4 dc
I-26A	2.64±0.3ab	14.3±0.9ab	135±26ab	99±18ab	288.33±46.3ab	2.76±0.1ab	0.75±0.04bc	18.85±0.5cd	10.31±0.3bc	294.8±146.8bc
I-26B	3±0.3a	15.11±1ab	191.6±57.7ab	117±25.2ab	381.44±130.2ab	2.76±0.1ab	0.78±0.03ab	19.02±0.4bc	10.29±0.2bc	360.8±86.3bc

Means with different letters in the same column are statistically different, according to the Tukey test ($p\leq 0.05$); ACC= accession; PlH= plant height; LW= leaf width; NFB= number of flower buds; NC= number of clusters; NF= number of fruits; NSF= seeds per fruit; SWe= seed weight; SL= seed length; SWi= seed width; PRS= production of seeds.

The first two principal components (PC) explained 57.66% of the total observed variation. The first component explained 34.84%, the second 22.82%. The variables with the highest descriptive value integrated in the PC1 are number of clusters, flower buds, leaf length, plant height, number of fruits per plant and weight of seeds. The PC2 integrated the variables: seed weight, seed width, leaf width, seed length, seeds per fruit, secondary branches and seed thickness (Table 3).

Table 3. Values of the principal component (PC) analysis with the variables of the highest descriptive value of the total variable in plant, fruit and seed of *J. curcas*.

Characteristics	PC1	PC2
Height (m)	0.301671	-0.165093
Diameter (mm)	0.265919	-0.095816
Primary branches	0.257299	-0.129041
Secondary branches	0.227279	-0.272969
Leaf length (cm)	0.308554	0.137911
Leaf width (cm)	0.163223	0.321368
Number of flower buds plant^{-1}	0.325952	-0.189021
Clusters tree^{-1}	0.34729	0.11357
Number of fruits plant^{-1}	0.30123	0.141859
Fruit length (mm)	0.020323	0.108105
Fruit width (mm)	0.20841	0.224884
Seeds fruit^{-1}	0.185248	0.281105
Fruit color	0.230813	-0.188615
Seed weight (g)	-0.108579	0.379092
Seed length (mm)	-0.204955	0.284673

Characteristics	PC1	PC2
Seed width (mm)	0.103584	0.3709
Seed thickness (mm)	-0.068378	0.263486
Seed weight (g)	0.283445	0.269734
Explained variance (%)	34.84	22.82
Cumulative variance (%)	34.84	57.66

The graphical representation of the first two principal components, group I was formed by the accessions I-34, I-32, I-26B, I-30, I-25, I-47, I-26A, I-64 and I-27, which were characterized by presenting a greater number of clusters, flower buds, leaf length, plant height, number of fruits per plant and weight of seeds.

Group II was formed by accessions I-22, I-62, I-48 and I-18, it was distinguished by presenting greater seed weight, seed width, leaf width, seed length, seeds per fruit, secondary branches, and seed thickness. In group III are accessions I-14, I-80, I-31 and I-04, this group presents intermediate values in stem diameter, fruit width, but lower values in clusters, fruits and seed weight. In group IV were accessions I-08, I-13, I-41 and I-77, this group stands out for presenting a greater number of primary branches, fruit color and fruit width, in addition to having an intermediate value in flower buds and seed weight (Figure 2).

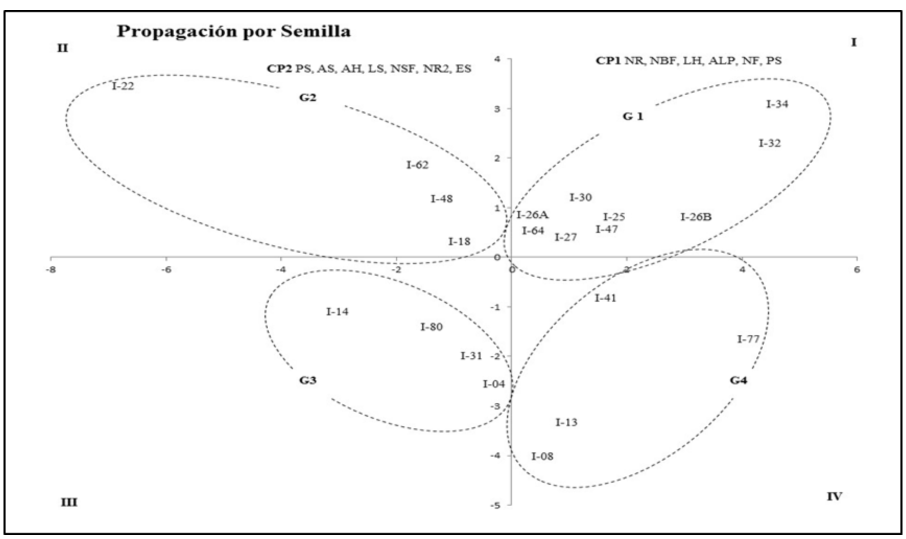

Figure 2. Scatter plot of 23 accessions of *Jatropha curcas* L., based on the first two principal components of 18 morphological and productive variables.

The cluster analysis gave rise to the formation of four groups (Figure 3), which differed in their conformation from those obtained in the principal component analysis. This difference is due to the fact that only the variables that explained PC1 and PC2 are used in the principal component analysis.

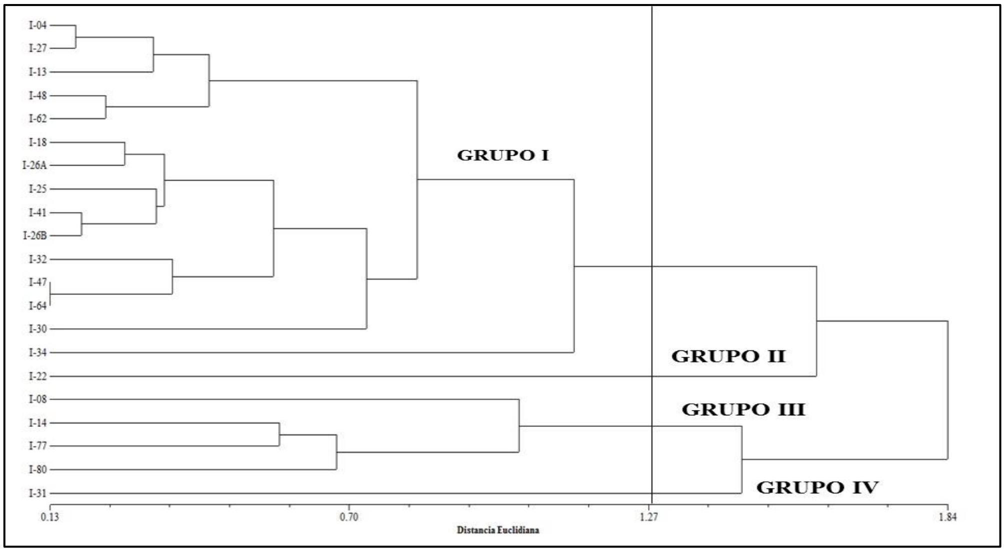

Figure 3. Dendrogram of 23 accessions of *J. curcas*, based on 18 outstanding variables.

Likewise, in the cluster analysis, when using all the variables evaluated in obtaining the dendrogram, it was obtained that group I included I-04, I-27, I-13, I-48, I-62, I-18, I-26A, I-25, I-41, I-26B, I-32, I-47, I-64, I-30 and I-34, which were characterized by having stem diameter of 65.67 mm, length and width of leaf of 14.1 and 14.74 cm, 161.63 in flower buds, clusters of 114.18, number of fruits with 380.83, length and width of fruit of 30.21 mm-23.26 mm and seed weight with 368.15 g.

In group II was accession I-22, which presented 14.76 cm in leaf width, seed weight with 0.84 g, width 19.82 mm and with a thickness of 10.61 mm respectively. While in group III were accessions I-08, I-14, I-77 and I-80, this group stood out for presenting a high average in plant height with 2.79 m, secondary branches of 29.5 and flower buds of 185, finally in group IV was accession I-31, which was characterized by presenting a low seed weight per plant (Table 4).

Table 4. Averages of the variation of four groups formed in the cluster analysis of 23 accessions of *J. curcas* L.

Variables	Group I	Group II	Group III	Group IV
Plant height (m)	2.73	1.99	2.79	2.74
Stem diameter (mm)	65.67	52.77	65.28	65.29
Number of primary branches	4.47	3	5	5
Number of secondary branches	27.93	14	29.5	25
Leaf length (cm)	14.01	13.28	13.75	13.74
Leaf width (cm)	14.74	14.76	14.07	14.48
Number of flower buds	161.63	13.28	185.05	185.4
Number of clusters	114.18	39.5	76.9	68.2
Number of fruits	380.83	142.5	222.97	190.2
Fruit length (mm)	30.21	28.6	29.58	30.8

Variables	Group I	Group II	Group III	Group IV
Fruit width (mm)	23.26	21.58	21.81	23.41
Number of seeds per fruit	3	2	2	2
Fruit color	5	4	5	5
Seed weight (g)	0.76	0.84	0.75	0.72
Seed length (mm)	18.66	19.82	18.48	18.09
Seed width (mm)	10.39	10.61	10.06	10
Seed thickness (mm)	8.81	9.15	8.9	8.94
Seed weight (g)	368.15	183.5	171.16	70.84

Authors such as Machado (2011), in one morphological characterization of accessions of different provenances of *J. curcas*, in Cuba, propagated by seed, found significant differences in morphological characteristics of height, number of primary, secondary and tertiary branches. Steinmann (2002) states that propagation by seed has greater production and tolerance to pests and diseases. In this regard, it is recognized that their populations present a great variability in their morphological structures (Toral *et al*., 2008), which could be a limitation for their domestication.

Investigations such as those of Henning (2004); Achten *et al*. (2008) mention that flower biology and heterogeneity in production cycles are characteristics that need to be improved to make a commercial crop possible, but it still lacks information on growing conditions, input response capacity of production and seed yield. Francis *et al*. (2005) mention that plant yield will depend on the conditions of the growing area, as well as genetics, plant age and management. Soil analysis. The type of soil is loamy-clayey (García, 1988) with a pH that tends to be moderately acidic. The pH obtained was within the acceptable parameter for *J. curcas*, since it can be sown in marginal soils with a pH of 6 to 8 (Kumar and Sharma, 2008).

The soil used to propagate the seed had a high concentration of nitrogen (N), a component required at a high concentration (Achten *et al*., 2008). Regarding the presence of phosphorus (P), this was independent of the depth at which the samples were taken. The amount of potassium (K) was higher in the sample taken at a shallower depth (20 mg L^{-1}), and important to increase the size of grains and seeds and the displacement of starch, sugar and oil.

Regarding organic matter, this was 6.28% in the sample taken from 0-20 cm. The texture was loamy-clayey and clay. This is contrary to studies indicating that *J. curcas* develops better in sandy or gravel soils with good aeration and does not tolerate flooded soils (Noda-Leyva *et al*., 2015).

Conclusions

The use of morphological and productive descriptors allowed identifying outstanding accessions in the plants of the 23 accessions of non-toxic *Jatropha curcas* L.; based on 18 variables. The accessions I-34, I-32 and I-47 were the most outstanding, with respect to a greater production in seed, number of flower buds, clusters and fruits, being the variables of greatest interest, coming in the same order from the regions of Capital, Nautla and Olmeca. The plants had a greater development in terms of height, number of primary branches, secondary branches, number of flower buds, fruits and seed production. These descriptors are important for the characterization of outstanding germplasm of *J. curcas* to be included in a genetic improvement program.

Bibliography

Achten, W. M. J.; Verchot, L.; Franken, Y. J.; Mathijs, E.; Singh, V. P.; Aerts, R.; and Muys, B. 2008. *Jatropha* bio-diesel production and use. Biomass and Bioenergy. 32(12):1063-1084. https://doi.org/10.1016/j.biombioe.2008.03.003.

Balota, E. L.; MachineskI, O.; Truber, P. V.; Scherer, A. and Souza, F. S. 2011. Physic nut plants present high mycorrhizal dependency under conditions of low phosphate availability. Braz. J. Plant Physiol. 23(1):33-44. https://doi.org/10.1590/S1677-04202011000100006.

Basha, S. D. and Sujatha, M. 2007. Inter and intra-population variability of *Jatropha curcas* L., characterized by RAPD and ISSR markers and development of population-specific SCAR markers. Euphytica. 156:375-386. https://doi.org/10.1007/s10681-007-9387-5.

Francis, G.; Edinger, R. and Becker, K. 2005. A concept for simultaneous wasteland reclamation, fuel production and socio-economic development in degraded areas in India; Need, potential and perspectives of *Jatropha* plantations. *In*: Natural Resources Forum. 29(1):12-24. https://doi.org/10.1111/j.1477-8947.2005.00109.x.

García, E. 1988. Modificaciones al sistema de clasificación climática de Köppen para adaptarlo a las condiciones de la República Mexicana. 4ta. Ed. Offset Larios, México. 246 p.

Guerrero, P. J. A.; Campuzano, L. F.; Rojas, S. y Pachon, G. J. 2011. Caracterización Morfológica y Agronómica de la Colección Nacional de Germoplasma de *Jatropha curcas* L. Orinoquia. 15(2):131-147. http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0121-37092011000200002.

Henning, R. K. 2004. The *Jatropha* system. In an integrated approach of rural development by utilization of *Jatropha curcas* L. (JCL). Calameo, Weissensberg, Germany. 105 p. https://www.calameo.com/read/0013656329b4f85182a36.

Kumar, A. and Sharma, S. 2008. An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas* L.); a review, Industrial Crops and Products. 28(1):1-10. http://dx.doi.org/10.1016/j.indcrop.2008.01.001.

Laviola, B. G.; Bhering, L. L.; Albrecht, J. C.; Marques, S. S. and Rosado, L. T. B. 2009. Caracterizacão morfo-agronômica do banco de germoplasma de pinhao manso. Uberlândia. 17(3):371-389. https://docs.bvsalud.org/biblioref/2018/09/911806/caracterizacao-morfo-agronomica-do-banco-de-germoplasma-de-pinh_6DevF5M.pdf.

Mabberley, J. D. 2005. The plant book, a portable dictionary of vascular plants. Cambridge University Press. 858 p.

Machado, R. y Suárez, J. 2009. Comportamiento de tres procedencias de *Jatropha curcas* en el banco de germoplasma de la EEPF “Indio Hatuey”. Pastos y Forrajes. 32(1):29-37. http://www.redalyc.org/articulo.oa?id=269119696003.

Machado, R. 2011. Caracterización morfológica y productiva de procedencias de *Jatropha curcas* L., Cuba. Pastos y Forrajes. 34(3):267-280. http://www.redalyc.org/articulo.oa?id=269121083003.

Makkar, H. P. S.; Francis, G. and Becker, K. 2007. Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. Animal. 1(9):1371-1391. https://doi.org/10.1017/S175173110700029.

Manurung, R. 2007. Valorization of *Jatropha curcas* using the biorefinery concept. Expert seminar on *Jatropha curcas* L. agronomy and genetics. FACT Foundation. Wageningen, The Netherlands. 28 p.

Martínez, H. J.; Martínez, A. A. L.; Makkar, H.; Francis, G. and Becker, K. 2010. Agroclimatic conditions, chemicals, and nutritional characterization of different provenances of *Jatropha curcas* L., from México. Eur. J. Sci. Res. 39(3):396-407. https://ipn.elsevierpure.com/en/publications/agroclimatic-conditions-chemical-and-nutritional-characterization.

Mujemdar, A. M. y Misar, A. V. 2004. Anti-infl ammatory activity of *Jatropha curcas* roots in mice and rats. J. Ethnopharmacology. 90(1):11-15. https://doi.org/10.1016/j.jep.2003.09.019.

Noda-Leyva, Y.; Pérez-Vázquez, A. y Valdés-Rodríguez, O. 2015. Establecimiento de tres especices de oleginosas bajo asociación. Agron. Mesoam. 26(2):232-332. http://dx.doi.org/10.15517/am.v26i2.19326.

Nwosu, M. O. and Okafor, J. I. 1995. Preliminary studies of the antifungal activities of some medicinal plants against Basidiobulus and some other pathogenic fungi. Myocoses. 38:191-195. https://doi.org/10.1111/j.1439-0507.1995.tb00048.x.

Oliveira, Y.; Hernández L.; Cruz, D. R.; Ramírez, W. y Lezcano, J. C. 2009. Nota técnica. Caracterización morfobotánica de tres especies cespitosas. Estación Experimental de Pastos y Forrajes Cuba. 32(2):1-8. https://www.redalyc.org/articulo.oa?id=269119694002.

Pérez-Vázquez, A.; Hernández-Salinas, G.; Ávila-Reséndiz, C.; Valdés-Rodríguez, O. A.; Gallardo-López, F.; García-Pérez, E. and Ruíz-Rosado, O. 2013. Effect of the soil water content on *Jatropha* seedlings in a tropical climate. International Agrophysics. 27(3):351-357. https://doi.org/10.2478/intag-2013-0004.

Rajagopal, R. 2008. Best practices for long-term *Jatropha* development. KnowGenix, Mumbai, India. 1-14 pp. https://www.calameo.com/read/00142415509223d76765d.

Rohlf, F. J. 2009. NTSYSpc: numerical taxonomy system, version 2.21. Exeter Software, New York. 43 p. https://www.researchgate.net/publication/246982444_NTSYS-pc_-_Numerical_Taxonomy_and_Multivariate_Analysis_System.

SAGARPA-SNICS. 2014. Secretaría de Agricultura Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA)-Servicio Nacional de Inspección y Certificación de Semillas (SNICS). Guía técnica para la descripción varietal. 22 p. https://www.gob.mx/snics/acciones-y-programas/guias-tecnicas-para-la-descripcion-varietal-238911.

Srivastava, P.; Behera, S. K.; Gupta, J.; Jamil, S.; Singh, N. and Sharma, Y. K. 2011. Growth performance, variability in yield traits and oil content of selected accessions of *Jatropha curcas* L. growing in a large-scale plantation site. Biomass and Bioenergy. 35(9):3936-3942. https://doi.org/10.1016/j.biombioe.2011.06.008.

Sosa-Segura M. P.; Angulo-Escalante, M. A.; Valdez-Torres, J. B.; Heredia, J. B.; Osuna-Enciso, T.; Allende-Molar, R. and Oomah, B. D. 2012. Phenology, productivity, and chemical characterization of *Jatropha curcas* L., as tool for selecting non-toxic elite germplasm. Afr. J. Biotechnol. 11(93):15988-15993. https://doi.org/10.5897/AJB12.2556.

Steinmann, V. W. 2002. Diversidad y endemismo de la familia Euphorbiaceae en México. Acta Bot. Mex. 61:61-93. https://www.redalyc.org/pdf/574/57406107.pdfTA.

Toral, O. C.; Iglesias, J. M.; Montes, S. O.; Sotolongo, J. A.; García. S. y Torsti, M. 2008. *Jatropha curcas* L., una especie arbórea con potencial energético en Cuba. Pastos y forrajes. 31(3):91-207. https://www.redalyc.org/pdf/2691/269119697001.pdf.

Trabucco, A.; Achten, W. M. J.; Bowe, C.; Aerts, R.; Van Orshoven, J.; Norgroves, L. and Muys, B. 2010. Global mapping of *Jatropha curcas* Yield based on response of fitness to and future climate. Global Change Biology Bioenergy. 2(3):139-151. https://doi.org/10.1111/j.1757-1707.2010.01049.x.

Valdés-Rodríguez, O. A., Sánchez-Sánchez, O., Pérez-Vázquez, A., y Zavala, I. 2013. Alometría de semillas de *Jatropha curcas* L., mexicanas. Rev. Mex. Cienc. Agríc. 4(5):967-978. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342013000900009.

Valdés-Rodríguez, O. A.; Gómez-Zúñiga, I.; Palacios-Wassenaa, O. M.; Sol-Quintas, G. and Pérez-Vázquez, A. 2020. Effect of pruning and organic fertilization over productive parameters of four Mexican provenances of *Jatropha curcas* L. Emir. J. Food Agric. 32(8):567-576. https://doi.org/10.9755/ejfa.2020.v32.i8.2133.

Valdés-Rodríguez, O. A.; Pérez-Vázquez, A.; Palacios-Wassenaar, O. and Sánchez-Sánchez, O. 2018. Seed diversity in native Mexican *Jatropha curcas* L. and their environmental conditions. Trop. Subtrop. Agroecoystems. 21(3):521-537. https://www.revista.ccba.uady.mx/ojs/index.php/TSA/article/download/2528/1194.

Wencomo-Cárdenas, H. B.; Pérez-Vázquez, A.; García-Pérez, E. y Valdés-Rodríguez, O. A. 2020. Caracterización morfoagronómica de accesiones no tóxicas de *Jatropha curcas* L. Pastos y Forrajes. 43(3):236-245. https://www.redalyc.org/journal/2691/269165823009/movil/.

Zavala, I.; García-Pérez, E.; Hernández, D.; Pérez-Vazquez, A.; and Ávila, C. 2016. Genetic diversity of *Jatropha curcas* L. in Veracruz state, México, and its relationships with content of phorbol esters. Global Adv. Res. J. Agric. Sci. 5(5):49-158. http://www.colpos.mx/wb_pdf/Veracruz/2016/2016_%2026.pdf.