Article

Morphological characterization of *Moringa oleifera* accessions from the South-Southeast of Mexico

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Abstract

Moringa oleifera is a plant with great capacity to adapt to different edaphoclimatic conditions. Environmental factors influence the morphology and phenology of this species. The objective was to characterize the morphology of 20 accessions of *Moringa oleifera* from the South-Southeast of Mexico. The seeds were collected from commercial cultivations in the states of Veracruz, Oaxaca, Guerrero, Chiapas and Yucatan. The seeds were sown in containers and transplanted two months after germination in the field with a completely randomized block design (CRBD). Every seven days the quantitative variables were recorded, and 301 days after transplantation, the morphological descriptors were evaluated. It was observed that accession C2 presented the highest growth (273 cm). Accession Y2 had a diameter of 43.22 mm and accession Y3 had 54 leaves. A high variation was found in leaf size, flower and stem color and the onset of flowering. Principal component analysis identified three groups. Principal component analysis (PCA) showed that the first five components explain 99.21% of the total variation and that components 1 (52.87%) and 2 (37.54%) contribute 90.41%. From the cluster analysis, three groups with 0.76 similarity resulted, based on Euclidean similarity. The morphological differentiation of the various accessions of moringa allowed corroborating varietal differentiation and the need to implement a genetic program of conservation, selection and breeding of moringa in the South-Southeast of Mexico.

Keywords: accessions, agroecosystems, moringa, phenotypes.

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Introduction

Plants have, in general, the ability to adapt to the various conditions that exist on the planet. This physiological adjustment allows them to survive in diverse and adverse climates. However, external factors influence growth and production through direct influence on their physiological and biochemical processes (Tesfay *et al*., 2011; Santiago and Bezerra, 2017). *Moringa oleifera* Lam., is a perennial, fast-growing plant species that presents great agroecological plasticity (Pérez *et al*., 2010). The global importance of this plant lies in its use to contribute to the improvement of nutrition and human health, to ensure food security, to promote economic development in rural areas and to mitigate the effects of climate change (NRC, 2006).

All parts of moringa have bioactive principles of nutritional and medicinal importance (Martín *et al*., 2013). In addition, it has a high storage capacity of active compounds that is determined by the variety or by the modification that the accession has undergone in the collected environment (Baiyeri *et al*., 2015). In India, the varieties of moringa: PKM-1, PKM-2, Jaffna, Chavakacheri Murungai, Chemmurungai, Kaadumurungai palmurungai, Puna murungai and Kodikkal murungai have been identified, which show phenological and morphological differences.

Morphological characterization is a fundamental tool for the selection, conservation, breeding and creation of new varieties (Popoola *et al*., 2016; Kumar *et al*., 2017). The study of accessions under homogeneous environmental conditions allows detecting the variability in the growth, flowering, number and size of leaves and fruits and allows identifying the resistance to various types of environmental stress (Resmi *et al*., 2005). Despite the great adaptability of the moringa plant, deciduous populations have been found in subtropical climates (Folkard *et al*., 1999).

Knowledge of morphological diversity in moringa can become a resource for its breeding through the section of elite varieties adapted to local conditions (Leone *et al*., 2015). The South-Southeast of Mexico has several moringa plantations. However, there is no detailed information on the morphological variation of the various accessions. Morphological variation in any plant can be attributed to edaphoclimatic, genetic, agronomic management factors or their combination (Chaves-Bedoya *et al*., 2017). The objective was to characterize the morphology of *M. oleifera* accessions from the Southeast of Mexico.

Materials and methods

Study area

The research focused on the south-southeastern region of Mexico due to the presence of commercial cultivations of moringa and this characteristic favored seed availability. The seeds of the accessions studied are from the states of Veracruz, Oaxaca, Guerrero, Chiapas and Yucatán (Table 1, Figure 1). The research was carried out at the College of Postgraduates, *Campus* Veracruz, geographically located at 19° 16’ 32” north latitude, 96° 16’ 32” west longitude, at an altitude of 16 m (Valdés *et al*., 2014). The climate is warm subhumid (AW_0), with an accumulated annual rainfall of 1 000 mm and an average annual temperature of 27 °C (Olguín, 1999).

Table 1. Origin of the seeds of *M. oleifera* from the South-Southeast of Mexico.

Num.	State	Accession	Municipality	Locality	Longitude	Latitude
1	Veracruz	V1	Soledad de Doblado	El Progreso	-96.4022719	19.0818742
2	Veracruz	V2	Paso del Macho	Loma Pelada	-96.5398368	18.9258796
3	Veracruz	V3	Tierra Blanca	Colonia Pemex	-96.3429545	18.435
4	Veracruz	V4	Misantla	Santa Cruz Hidalgo	-96.8628092	19.9555656
5	Oaxaca	O1	Santa Cruz Xoxocotlán	San Juan Bautista La Raya	-96.7280556	16.9791667
6	Oaxaca	O2	Santa María Huatulco	La Herradura	-96.3658333	15.7772222
7	Oaxaca	O3	Mariscala de Juárez	Guadalupe la Huertilla	-98.1088889	17.8513889
8	Oaxaca	O4	Tuxtepec	San Juan Bautista	-96.1286697	18.087694
9	Guerrero	G1	Acapulco de Juárez	Bejuco	-99.6977778	16.8216667
10	Guerrero	G2	Acapulco de Juárez	Parotillas	-99.61558371	16.8787834
11	Guerrero	G3	Acapulco de Juárez	Concepción	-99.66028879	16.8799601
12	Guerrero	G4	Tecpan de Galeana	Mitla	-99.89343517	16.8789425
13	Chiapas	C1	Tuzantán	Villa Hidalgo	-92.374722	15.108056
14	Chiapas	C2	Tuxtla Gutiérrez	Colonia La Salle	-93.0868889	16.7429444
15	Chiapas	C3	Tuxtla Gutiérrez	Santa Cruz	-93.108986	16.783481
16	Chiapas	C4	Tuxtla Gutiérrez	San Juan	-93.103645	16.747307
17	Yucatán	Y1	Tzucacah	Tzucacah	-89.0391111	20.0720278
18	Yucatán	Y2	Mérida	Frac. el Parque	-89.5872222	20.9711111
19	Yucatán	Y3	Peto	Teshan	-88.62125	20.1486389
20	Yucatán	Y4	Baca	Felipe Carrillo Puerto	-89.6070099	20.9954688

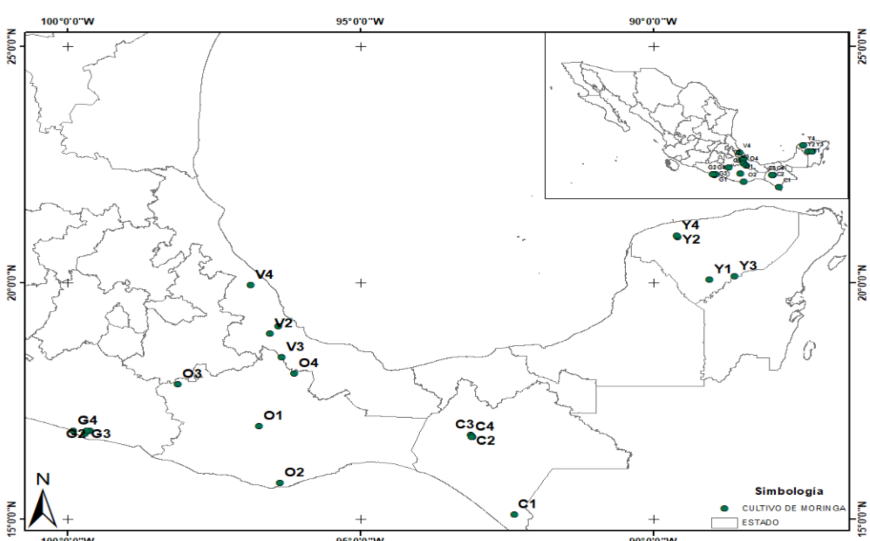

Figure 1. Geographical location of the collection points of *M. oleifera* in the South-Southeast of Mexico.

Biological material

Moringa seeds were collected from different commercial cultivations in the South-Southeast of Mexico during the months from February to May 2018. Thirty healthy seeds were selected from each collection point and the variables of length, thickness and weight of the seed were measured. Twenty accessions were evaluated, which are shown in (Table 2).

Table 2. Morphological variables of moringa accessions from the South-Southeast of Mexico.

Num.	Accession	Average weight (mg) ± standard error	Average length (mm) ± standard error	Average thickness (diameter) (mm) ± standard error
1	V1	364.33** ±8.19	11.93 ±0.26	8.33 ±0.14
2	V2	296.67 ±11.31	9.50 ±0.24	7.33 ±0.18
3	V3	325.33 ±10.5	8.93 ±0.18	8.5 ±0.18
4	V4	331.43 ±4.59	9.57 ±0.2	10.43 ±0.3
5	O1	332.33 ±6.91	11.67 ±0.23	9.5 ±0.13
6	O2	379.67 ±8.2	11.33 ±0.19	10.63 ±0.15
7	O3	324.67 ±6.19	13.53 ±0.25	10.77 ±0.09
8	O4	364.67 ±8.63	11.87 ±0.19	11.37 ±0.15
9	G1	309.67 ±9.83	12.43 ±0.23	9.53 ±0.13
10	G2	356 ±7.99	13.97 ±0.33	10 ±0.16
11	G3	408.67 ±10.42	12.97 ±0.28	11.07 ±0.13
12	G4	580.67 ±12.05	14.2 ±0.18	12.3 ±0.12
13	C1	485.33 ±10.36	14.9 ±0.35	10.93 ±0.21
14	C2	461 ±10.3	13.8 ±0.24	11.83 ±0.14
15	C3	480 ±8.04	13.87 ±0.25	11.97 ±0.14
16	C4	308.33 ±7.08	12.13 ±0.24	9.53 ±0.22
17	Y1	337.67 ±9.38	13.03 ±0.23	11.2 ±0.18
18	Y2	460 ±11.25	14.3 ±0.35	10.6 ±0.19
19	Y3	349.67 ±8.7	12.47 ±0.22	10.37 ±0.21
20	Y4	428.67 ±12.76	13.6 ±0.27	11.27 ±0.23

V= Veracruz; O= Oaxaca; G= Guerrero; C= Chiapas; Y= Yucatán; **= average value of 30 seeds.

Sowing and transplanting

The seeds were sown in black nursery bags of 27 x 27 cm. The substrate used was composed of soil, manure-vermicompost and sand (5:4:1). After 15 days of germination, the seedlings of greater vigor and of a similar size were selected and two months later, they were transplanted in the field. The type of soil in the field was clay-loam.

Treatments and experimental design

The experimental design was completely randomized blocks with five repetitions. The size of the area used was 900 m^2. The distance between individuals and furrows was 3 m. Every seven days, the variables of height, basal diameter (10 cm from the ground), number of branches and leaves were recorded. Two liters of water was applied daily to each plant through drip irrigation.

Morphological characterization

For morphological characterization, quantitative and qualitative descriptors were used for each organ of the plant. The quantitative ones recorded were: height, stem diameter, number of leaves, number of branches, number of flowers, leaf length, leaf width, petiole length, leaflet length, leaflet width and days to first flowering. For qualitative descriptors, those published by Mgendi *et al*. (2011); Zhigila *et al*. (2015); Popoola *et al*. (2016) were used. The qualitative descriptors were: leaf petiole color (1: light green, 2: green, 3: light violet, 4: medium violet, 5: intense violet), leaf shape (1: oval, 2: oblong, 3: oblong oval and 4: elliptical), leaf apex (1: obtuse and 2: acute), leaf pubescence (0: absent and 2: present), flower color (1: white, 2: white-cream, 3: white-pink, 4: white-cream-pink and 5: pinkish), purple spots on the flowers (0: absent and 1: present) and anther color (1: yellow and 2: orange).

Statistical analysis

The average values of the descriptors were evaluated by descriptive statistics. The correlation coefficient, principal component analyses and cluster analysis were performed through a hierarchical grouping with coefficient of variation in the unweighted pair group method (Euclidean distance). The two-dimensional scatter plot was performed through the percentage variation of the first two principal component analyses using the PAST program Version 3.0.

Results and discussion

Germination

The highest percentage of germination was obtained in accession G3 (100%) and the lowest percentage was 13% for accessions C4, O1, G4, C1, C4 and Y1. At the time of transplantation, accession V3 measured 108 cm, being the greatest height. Significant statistical differences ($p< 0.05$) were observed in the height and diameter of the stem of the 20 accessions evaluated. Accession C3 had the largest diameter and the largest number of leaves corresponded to accession O4 (Table 3).

Table 3. Variables recorded of *Moringa oleifera* at the time of transplantation.

Num.	Accession	Germination (%)	Height (cm) (mean ± standard error)	Diameter (mm) (mean ± standard error)	Number of leaves (mean ± standard error)
1	V1	60*	101.8 ±5.12 de	9 ±0.55 cdefgh	8.6 ±0.24 ab
2	V2	13	98.6 ±5.82 de	8.2 ±0.37 bcdefg	7 ±0.32 a
3	V3	50	108 ±7.35 e	10.25 ±0.48 gh	7.25 ±0.48 a
4	V4	63	59.4 ±2.86 a	5.8 ±0.37 a	6.6 ±0.24 a
5	O1	13	98.6 ±3.52 de	8.6 ±0.4 cdefgh	7.4 ±0.24 ab
6	O2	10	85.8 ±2.29 cde	8 ±0.55 abcdef	7.8 ±0.2 ab
7	O3	43	84 ± 4.89 bcd	9.4 ±0.68 defgh	6.6 ±0.24 a
8	O4	47	103.4 ±1.83 de	10 ±0.32 fgh	12.4 ±3.71 b

Num.	Accession	Germination (%)	Height (cm) (mean ± standard error)	Diameter (mm) (mean ± standard error)	Number of leaves (mean ± standard error)
9	G1	90	62 ±2.21 ab	6.2 ±0.37 ab	6.6 ±0.24 a
10	G2	33	84.4 ±3.26 bcd	7.2 ±0.2 abcd	7.2 ±0.2 a
11	G3	100	72.4 ±3.3 abc	7 ±0.32 abc	6 ±0.63 a
12	G4	13	95.8 ±2.94 de	7.6 ±0.24 abcde	7.8 ±0.37 ab
13	C1	13	85.8 ±3.07 cde	8.6 ±0.4 cdefgh	6.6 ±0.75 a
14	C2	50	82 ±1.64 abcd	7 ±0.55 abc	7.4 ±0.68 ab
15	C3	63	102.5 ±10.31 de	10.5 ±0.5 h	9.75 ±0.25 ab
16	C4	13	86.75 ±3.35 cde	10 ±0.41 fgh	8.5 ±0.29 ab
17	Y1	13	93 ±2.94 cde	8.6 ±0.4 cdefgh	6.6 ±0.75 a
18	Y2	77	90 ±2.76 cde	10.2 ±0.37 fgh	7.2 ±0.37 a
19	Y3	60	96.6 ±4.35 de	9.6 ±0.4 efgh	8 ±0.32 ab
20	Y4	23	99.8 ±7.7 de	8.4 ±0.4 bcdefgh	8.2 ±0.2 ab

*= average value of 10 seedlings. Means with similar letters do not present significant statistical differences ($p > 0.05$).

Great variation was found in the percentage of germination of the accessions sown. This variation is attributed to seed quality and storage time before sowing (Du Toit *et al*., 2017). In addition to this, genetic potential and environmental factors such as temperature, precipitation and altitude influence the development of the seed before collection and determine its size and weight (Baiyeri *et al*., 2015; Ledea-Rodríguez *et al*., 2018).

This process affects the viability of seeds of more than one year of storage in temperature ranges of 23 to 25 ºC. Therefore, it is recommended that the seeds be preserved in the pods (Fotouo *et al*., 2015). The average number of germination days of the accessions sown was 11. The earliest gemination occurred at 8 days and the latest at 14 days. This interval is like the 6 and 13 days reported by Popoola *et al*. (2016); Zaku *et al*. (2015); while Kumar *et al*. (2014) mentioned that germination occurs between 10 and 12 days after sowing. Ramos *et al*. (2010) reported that germination begins from 8 days after sowing and at 25 days, the primary leaves appear.

Height

Accessions C2 and G2 were the largest and reached an average height of 273 and 271 cm, respectively. Accession Y4 had an average height of 164 cm, being the lowest growth recorded during the 301 days after transplantation (DAT) (Figure 2).

At six months after transplantation, the minimum and maximum height were 1.45 and 2.25 m, respectively. These values are lower than the 5.17 and 10.27 m reported by Popoola *et al*. (2016). This smaller size can be attributed to the lack of precipitation, since water has a direct effect on plant growth because in drought conditions, cell division and expansion decreases (Taiz and Zeiger, 2009).

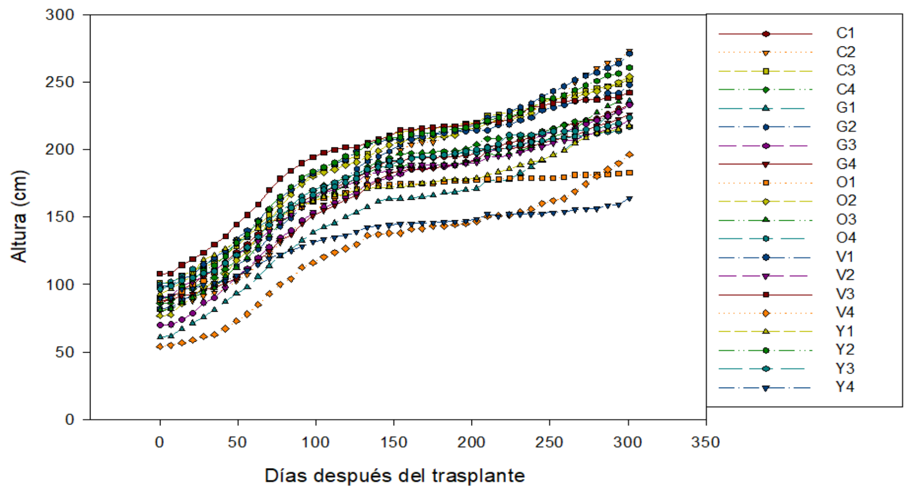

Figure 2. Plant height of the 20 accessions of *Moringa oleifera* collected in the South-Southeast of Mexico. Period: 0 to 301 DAT.

In relation to the number of branches, there were few and these emerged after 2 m in height. Popoola *et al*. (2016) mentions that the branching is moderate. Dao and Kabore (2015) recorded in moringa, at two months, from 8 to 15 branches per tree. In this work, there was a monopodial growth in the accessions evaluated.

Stem diameter

The largest diameter at a height of 10 cm from the ground was observed in accession Y2 with an average value of 43.22 mm, and the lowest value corresponded to accession Y4 with 25.61 mm at 301 days after transplantation. The most frequent stem colors were gray and whitish gray. Panshin and Zeeuw (1970) mention that the thickening of the stem is due to related processes in xylem and phloem. Therefore, they may differ between accessions. The thickening of the stem and its morphology among moringa ecotypes is diverse due to the great plasticity it presents (Förster *et al*., 2015).

Leaves

After transplantation, defoliation was observed in all accessions. At 301 DAT, accession Y3 had 54 leaves, the highest value being. Accession O1 presented 9 leaves, being the accession with the lowest average number of leaves. The shortest leaf length was 28.8 cm (Y3) and the longest was 47 cm (C2). The leaf width fluctuated between 16.8 (O1) and 38.33 cm (Y1). The presence of pubescence was recorded in accessions G4, C3 and G2. These values are higher than the range of 21.4 to 54.2 cm long and 10.1 to 41.6 cm wide reported by Zhigila *et al*. (2015). Dao and Kabore (2015) reported average leaf lengths from 16 to 44 cm and values from 10.5 to 34 cm wide, with a number of pinnas of 5 to 12 per leaf.

Leaf length is influenced by relative humidity and average annual precipitation. Phenotypic characteristics are affected by edaphic factors and result in epigenetic changes (Shahzad *et al*., 2013). Moringa leaves are consumed for their high nutritional value (Förster *et al*., 2015). Therefore, the size, color and number of leaves represent an important characteristic to produce biomass, nutritional content and genetic improvement.

The presence of purple pigmentation in the petiole and rachis of accessions C1, O2 and Y2 was also identified. The dark color on the leaf represents a greater amount of chlorophyll and the existence of this photosynthate promotes greater growth (Opare-Obuobi, 2012).

The violet pigmentation in the leaf petiole is determined by the anthocyanin content. The presence of anthocyanins is determined by environmental conditions and can be purple or pink in color. Usually, crops in areas under drought have higher anthocyanin production as a mechanism to avoid stress (Shahzad *et al*., 2013). The presence of pubescence on the leaves, tender shoots and filaments of the anther was noted. There was defoliation caused by high temperatures and little precipitation. Vasconcelos *et al*. (2019) mentioned that water stress caused by lack of precipitation influences leaf morphology and plant physiology. In this work, the effect of stress on the defoliation and yellowing of the leaves was observed.

Flowers

The beginning of flowering was recorded by counting the days since the sowing of the accessions. Accession O4 was the first to start the flowering process at 129 days after sowing (das). The last accession to flower was G3 at 240 das. Accessions Y2 and Y5 had pinkish-white flowers, C2 and V3 creamy white and O1 white flowers. Purple spots were identified in accessions G2 and V1 (Table 4). Flowering in cultivated accessions began at 129 days and continued during the months of October-May. However, the fall of flowers prevented many from reaching anthesis, limiting the pollination process.

Table 4. Central tendency values for quantitative descriptors of *Moringa oleifera* Lam.

Num.	Descriptor	Mean	Standard deviation	Maximum	Minimal	Variance
1	Height (cm)	231.45*	27.37	273 (C2)	164 (Y4)	749.32
2	Diameter (mm)	32.58	4.75	44 (Y2)	23.6 (O1)	22.59
3	No. leaves	20.72	9.85	54 (Y3)	9.8 (O1)	97.09
4	No. branches	2.64	2.94	12.6 (C2)	0.4 (O1)	8.64
5	No. flowers	0.52	0.75	2.67 (Y1)	0 (V4, O1 y O3)	0.56
6	No. fruits	0.35	0.43	1.6 (O2)	0 (V4, O1, O3 y G1)	0.19
7	Leaf length (cm)	37.72	4.51	47 (G1)	28.8 (Y3)	20.33
8	Leaf width (cm)	26.71	5.72	38.33 (Y1)	16.8 (O1)	32.72
9	Petiole length (cm)	10.46	1.51	13 (C1)	7.6 (Y3)	2.27
10	Leaflet length (mm)	15.9	2.22	21.75 (Y2)	12 (Y3)	4.92
11	Leaflet width (last) (mm)	7.44	1.18	9.2 (V2)	5 (O3)	1.4
12	Days to first flowering	180.53	28.89	240 (G3)	129.6 (O4)	834.51

*= average value of 5 plants. Values obtained at 301 DAT and beginning of flowering obtained at DAS.

Flowering in moringa can occur once or twice a year, depending on the environmental conditions (temperature and precipitation). Price (2000) mentioned that flowering can occur four times during the year. The pigmentation of the flowers varied from white, creamy white and pinkish white. Some accessions had purple pigmentation on the petals. Popoola *et al*. (2016) recorded white flowers with purple pigmentation, white or creamy white without pigmentation and 50% of flowering occurred in the 161 and 167 days. Moringa is a species that presents great variability in the color of its flowers and in some varieties of India, flowers with pink and dark pink base have been recorded (PPV and FR, 2001).

Several studies have stated that pink and dark pink flowers receive more visits from bumblebees than yellow ones. This factor represents, apparently, a strategy of adaptation and reproduction (Bradshaw and Schemske, 2003; Reverté *et al*., 2016). Therefore, cross-pollination between moringa accessions is promoted and facilitates the creation of new varieties. Factors such as temperature and soil moisture influence the increase of flowers, pollen viability and decrease the number of fruits (Muhl *et al*., 2013).

Pearson’s correlation coefficient (r) of morphological characters

The Pearson correlation matrix among the quantitative descriptors of moringa is shown in Table 5. A positive correlation was found between the length and width of the leaf (r= 0.857), and leaf length and petiole length (r= 0.851). A correlation was also found between diameter and height (r= 0.675). A negative correlation was identified between the days to first flowering and the number of flowers (r= - 0.599) and with the number of fruits (r= - 0.361).

Table 5. Correlation matrix of quantitative descriptors of *Moringa oleifera* at 301 DAT.

	Height	Diameter	Num. leaves	Num. branches	Num. flowers	Num. fruits	L. leaf	W. leaf	L. petiole	L. leaflet	L. leaflet	DF. flowering
Height (cm)	1											
Diameter (mm)	0.675*	1										
Num. leaves	0.042	0.103	1									
Num. branches	0.333*	0.18	0.318*	1								
Num. flowers	0.134	0.088	0.166	-0.104	1							
Num. fruits	0.284	0.344*	-0.226	0.025	0.364*	1						
L. leaf (cm)	0.368*	0.382*	-0.422*	-0.363*	0.073	0.106	1					
W. leaf (cm)	0.327*	0.454**	-0.285	-0.22	0.324*	0.175	0.857*	1				
L. petiole (cm)	0.187	0.24	-0.472*	-0.484*	0.207	0.109	0.851*	0.686*	1			
L. leaflet (mm)	0.249	0.386*	-0.47*	-0.048	-0.088	0.24	0.288	0.219	0.304*	1		
W. leaflet (mm)	-0.085	0.045	-0.187	-0.117	0.084	0.269	0.068	0.017	0.126	0.636*	1	
DF. flowering	-0.161	-0.134	-0.127	-0.113	-0.599**	-0.361*	-0.1	-0.19	-0.219	0.078	-0.34*	1

**= significant correlation at 0.01; *= significant correlation at 0.05.

Principal component analysis

The principal component analysis demonstrated variability in morphological characters in the 20 moringa accessions (Table 6). The percentage of variation was 52.87, 37.54, 6.16, 1.98 and 0.63 for components 1, 2, 3, 4 and 5, respectively.

Table 6. Principal component analysis for morphological descriptors of *Moringa oleifera* at 301 DAT.

Num.	Descriptor	PC 1	PC 2	PC 3	PC 4	PC 5
1	Height (cm)	0.6	0.785	0.029	-0.11	-0.094
2	Diameter (mm)	0.075	0.091	0.006	0.291	0.856
3	Number leaves	0.04	-0.025	0.906	0.378	-0.09
4	Branches	0.026	0.023	0.113	-0.157	0.179
5	Number flowers	0.013	-0.009	0.003	0.025	-0.03
6	Number fruits	0.006	0	-0.01	-0.009	0.038
7	Leaf length (cm)	0.042	0.046	-0.264	0.458	-0.238
8	Leaf width (cm)	0.064	0.036	-0.276	0.713	-0.102
9	Petiole length (cm)	0.013	0.002	-0.093	0.114	-0.062
10	Leaflet length (mm)	0.006	0.024	-0.099	-0.023	0.339
11	Leaflet width (last) (mm)	0.008	-0.014	-0.026	-0.019	0.115
12	Leaves	0	0	0	0	0
13	Leaf petiole color	0.005	0.009	-0.001	0.014	0.067
14	Leaf shape	0	0	0	0	0
15	Leaf apex (in mature leaf)	0	0	0	0	0
16	Pubescence on the leaf	0.004	-0.003	0.001	-0.011	-0.029
17	Days to first flowering	-0.791	0.609	0.034	0.043	-0.006
18	Flower color	0.008	0.001	-0.004	0.015	0.103
19	Purple spots on flowers	-0.003	0.008	0.003	0.007	0.016
20	Anther color	0.002	-0.002	-0.003	-0.007	0.027
	Eigenvalue	938.953	666.755	109.553	35.323	11.289
	(%) variance	52.874	37.546	6.169	1.989	0.636

PC= principal component.

The two-dimensional Figure 3 of the analyses of principal components 1 and 2 shows 3 groups. Group A comprises accessions O2, Y2, C2, G2, C3, V2, G4, C1, V3, Y1, O4 and V1. Group B comprises accessions G3, O3, G1, Y3 and C4. In group C, populations V4, O1 and Y4 were identified (Figure 3). The grouping was the result of the PCA based on the analysis of morphological descriptors.

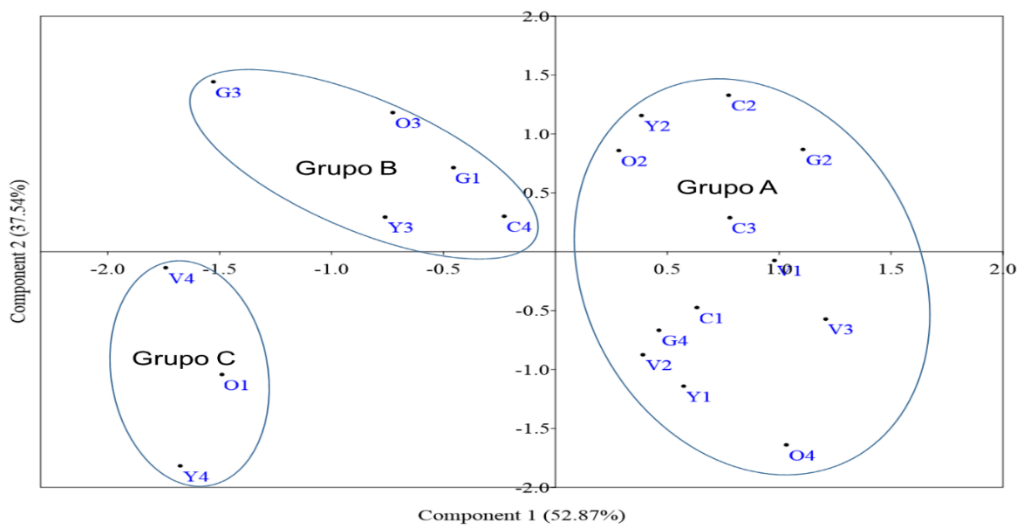

Figure 3. Dispersion of components 1 and 2 for the 20 accessions of *Moringa oleifera* Lam., from the South-Southeast of Mexico.

Cluster

Two subgroups were formed in group A: I (O2, Y2, C2, G2) and II (O4, G4, C1, Y1, V2, V3, C3 and V1). In group B, the subgroups: I (O3, G1, C4, G3) and II (Y3) were formed. In group C, accessions V4, O1 and Y4 were identified (Figure 4).

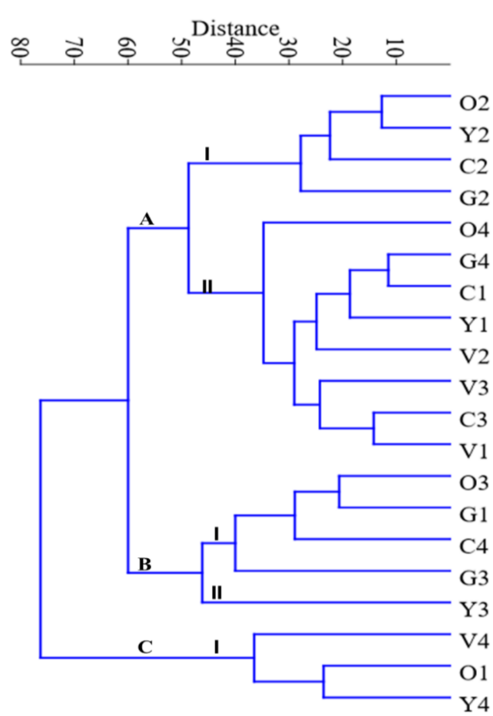

Figure 4. Cluster analysis based on morphological data from 20 accessions of *Moringa oleifera* collected in the South-Southeast of Mexico.

Conclusions

There is a morphological diversity in the moringa accessions from the South-Southeast of Mexico. This diversity can serve to reinforce the knowledge of moringa and expand information regarding its physiology, phenology and production. The morphological knowledge of the accessions will allow the creation of programs of conservation, selection and generation of elite materials with greater adaptive potential, resistance to pests and diseases and with greater productive capacity and nutritional content.

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