Article

Agronomic characterization of *Salvia hispanica* L. germplasm

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Abstract

Salvia hispanica L. (chia) is an herbaceous plant native to Mexico, belongs to the Lamiaceae family. The crop was banned and replaced by other cereals during the Conquest. Due to the nutritional content and nutraceutical properties it possesses, it has been reintroduced and is currently considered a highly nutritious potential food. The area sown is increased annually, the cultivated materials are usually local or introduced genotypes, because there are few improved varieties. With the aim of identifying outstanding accessions, oriented to greater efficiency of the crop, during the 2017 spring-summer agricultural cycle, 32 accessions of *S. hispanica* were agronomically characterized, in seven environments, under a design of randomized complete blocks with three repetitions. The following variables were evaluated: plant height, stem diameter, plant weight, number of spikes, grain weight per plant and yield per hectare. Accessions 1, 2, 12 and 22 had higher seed yield per ha, plant height, number of flower spikes, fruits per spike and dry plant weight. The average seed production was 924 kg ha^{-1}. The best environment for chia production was Rancho San Lorenzo, Metepec. The cluster analysis grouped the accessions into five clusters, grouping them by their yield and related variables.

Keywords: agronomic variables, chia, genetic variability.

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Introduction

Salvia hispanica L. is an herbaceous plant of the Lamiaceae family, native to the mountainous areas of southwestern Mexico, Guatemala, and Nicaragua (Lobo *et al*., 2011). The basis of the diet of the Indigenous peoples of Mexico, it was one of the four main crops of the Aztecs, surpassed only by corn (*Zea mays* L.), beans (*Phaseolus vulgaris* L.) and chili (*Capsicum annuum* L.). During the conquest of New Spain, its production decreased until almost disappearing, due to the reduction of the pre-Hispanic population and the implementation of cereal cultivation (Xingú *et al*., 2017).

In recent decades it has resurfaced, the nutraceutical properties and its attractive nutritional benefits have expanded its consumption (Xingú *et al*., 2017), it has oil with 68% of α-linolenic acid, the most important of the omega-3 fatty acids for human consumption, which makes it the richest vegetable source in antioxidants (Orona-Tamayo *et al*., 2017), vitamins B1, B2 and B3 (Jamshidi *et al*., 2019), fiber, proteins and minerals such as phosphorus, calcium, potassium, magnesium, iron, zinc and sodium (Michajluk *et al*., 2018).

In addition, it has medicinal properties (Deka and Das, 2017), has beneficial effects for the treatment of metabolic syndrome (Lombardo and Chicco, 2017), regulates blood glucose and promotes blood clotting (Nieman *et al*., 2012), decreases bad cholesterol and triglycerides, and improves intestinal function (Sandoval-Oliveros and Paredes-López, 2013). The global demand for chia began in the nineties, it is currently grown in Argentina, Bolivia, Paraguay, Australia and Mexico mainly (Busilacchi *et al*., 2015), where its consumption increases day by day, being exported to Peru, the United States of America, Chile, Germany, the Netherlands, the United Kingdom, Denmark, Japan, Canada, New Zealand, Singapore and South Africa (Suárez, 2018).

In Mexico, the commercial production of this species takes place in eight states. Although during the 2006-2009 period, the area sown with chia was less than 50 ha, by 2010 it increased to 2 300 ha, a figure that increased constantly until the 2013 cultivation cycle, which exceeded 18 000 ha. However, from 2014, it registered a decreasing trend and during the 2017 spring-summer cycle, it was grown only on 5 400 ha with a production of 3 200 tons (SIAP, 2019). Reduction due to factors such as: lack of experience on the cultivation, ignorance of nutritional properties and limited information on improved varieties (Sosa-Baldivia and Ruiz-Ibarra, 2016).

The state of Jalisco is the largest producer, concentrating more than 65% of the cultivated area which contributes a volume of more than 2 000 tons, equivalent to 63% of production (SIAP, 2019). Chia cultivation is mostly based on regional genotypes. Although germplasm banks have been established in institutions such as the Chapingo Autonomous University (UACH, for its acronym in Spanish), the National Institute of Nuclear Research (ININ, for its acronym in Spanish), the Institute of Agricultural, Aquaculture and Forestry Research and Training of the State of Mexico (ICAMEX, for its acronym in Spanish), the collection of accessions of the company Chíablanca SC de RL located in Acatic, Jalisco stands out, which concentrates collections from the different producing areas.

Information on the characterization of materials of this species is scarce, wild, semi-domesticated and domesticated populations have been typified (Calderón-Ruiz *et al*., 2021). Hernández and Miranda (2008) studied three ecotypes of cultivated chia, finding similarity in seed size and inflorescence density, but with differences in biological cycle, length and width of corolla, width of inflorescence and height of plant, and they concluded that among the morphological structures that differentiate cultivated *S. hispanica* from the wild are: flower size, density of whorls in the inflorescence, seed weight and duration of the biological cycle.

Studies carried out by Sosa-Baldivia *et al*. (2017) report potential yields of 1 723 kg ha^{-1}, which they relate to the number of plants per m^2, plant height and main inflorescence length, while Grimes *et al*. (2018) reported a production of 1 274.7 kg ha^{-1} of the Sahi Alba 914 variety. Yields are related to a higher number of branches plant^{-1} and inflorescences plant^{-1} (Pereira *et al*., 2020). Currently, studies have focused on demonstrating the properties as a functional food (Grancieri *et al*., 2019) but the work of describing the available materials of this species has been insufficient, so the present research arose with the aim of agronomically characterizing chia accessions from the main producing regions of Mexico.

Materials and methods

Genetic material

Two hundred fifty grams of seeds were obtained from each of the 32 chia accessions (Table 1), two were donated by the Institute of Agricultural, Aquaculture and Forestry Research and Training of the State of Mexico (ICAMEX, for its acronym in Spanish), six by the germplasm bank of the Chapingo Autonomous University (UACH, for its acronym in Spanish), 13 by the company Chíablanca, SC de RL (located in Acatic, Jalisco) and 11 provided by the National Institute of Nuclear Research (ININ, for its acronym in Spanish).

Table 1. Accessions of *Salvia hispanica* L.

Number	Genealogy	Seed color	Institution
1	CHGRD	Black	ICAMEX
2	CHCRI	Black	ICAMEX
3	ININ1	Black	ININ
4	ININ2	Marbled Grey	ININ
5	ININ3	White	ININ
6	ININ4	Black	ININ
7	ININ5	Black	ININ
8	ININ6	Black	ININ
9	ININ7	Marbled Grey	ININ
10	ININ8	White	ININ
11	ININ9	Marbled Grey	ININ
12	ININ10	White	ININ
13	ININ11	Black	ININ
14	17Pz	White	Chíablanca SC de RL
15	83FB5B	White	Chíablanca SC de RL
16	59 Normal	Black	Chíablanca SC de RL
17	66 Brown Grain	Brown	Chíablanca SC de RL
18	122 Az	Black	Chíablanca SC de RL

Number	Genealogy	Seed color	Institution
19	64	Black	Chíablanca SC de RL
20	SLVTTLA	Black	Chíablanca SC de RL
21	B54	White	Chíablanca SC de RL
22	CRIPINA	Mottled	Chíablanca SC de RL
23	680	Black	Chíablanca SC de RL
24	346	Black	Chíablanca SC de RL
25	30Pz	White	Chíablanca SC de RL
26	P75ZN	Marbled Grey	Chíablanca SC de RL
27	CNPGA	Black	Chapingo germplasm bank
28	CNPGB	Black	Chapingo germplasm bank
29	CPJGA	Marbled Grey	Chapingo germplasm bank
30	CPJGB	Marbled Grey	Chapingo germplasm bank
31	CBJGA	White	Chapingo germplasm bank
32	CBJGB	White	Chapingo germplasm bank

Evaluation localities

The crops were established in the 2017 spring-summer agricultural cycle in the localities whose characteristics are shown in Table 2.

Table 2. Characteristics of the localities where the crop of chia was established.

Characteristic	CPB	RSL	SFT	XAL	SJX
North latitude	19°24’49”	19°14’40”	19°18’17”	19°10’51”	19°00’50”
West latitude	99°41’29”	99°35’36”	99°46’29”	99°25’41”	99°31’52”
Altitude (m)	2 640	2 606	2 750	2 770	2 330
Climate	C(w2)(w)ig	C(w2)(w)ig	C(w2)(w)ig	Cwb	C(w2)(w)ig
Soil	Vertisol	Phaeozem	Vertisol	Andosol	Andosol
Average annual rainfall (mm)	790	980	777	1 069	1 000
Landform	Plain	Plain	Plain	Mountain	Mountain

CPB= El Cerrillo Piedras Blancas (municipality of Toluca); RSL= Rancho San Lorenzo (Metepec); SFT= San Francisco Tlalcilalcalpan (Almoloya de Juárez); XAL= Xalatlaco (Xalatlaco); SJX= San Juan Xochiaca (Tenancingo).

Experimental design and unit

An experimental design of randomized complete blocks with three repetitions per environment was used. The plot consisted of three furrows of 4.5 x 0.8 m, each furrow with 90 plants at a distance of 0.05 m. The central furrow was the useful experimental unit.

Establishment and conduct of the experiment

The preparation of the soil consisted of fallow, two passes of harrowing and furrowing. The sowing was carried out manually by steady flow on the ridge of the furrow in May 2017. Subsequently, a thinning was carried out to adjust the required density. Between 30 and 45 days after the emergence of the seedlings, weed control was performed manually.

Variables evaluated

Ten plants were selected from each experimental unit and the following variables were evaluated: plant height (from the base of the stem to the apex of the main spike, recorded in cm), diameter of the base of the stem (mm), dry weight of mature plant (grams), number of fruits per floret in the main spike, main spike length (cm), main spike length from node (cm), number of lateral branches, number of total flower spikes per plant, harvest index (ratio between seed weight and total weight of unthreshed plant) and yield in kg (plants contained in one linear meter).

Data analysis

In the statistical package SAS version 6.01, the following analyses were carried out: variance (individual and combined), comparison of means between sites and between cultivars (individual and combined). The 14 interrelationships between cultivars and between variables were determined by a principal components analysis (Sánchez, 1995).

Results and discussion

Significance ($p \leq 0.01$) was obtained between environments (E), between chia accessions (C) and in the interaction of accessions (C) by environments (E) for dry weight of plant, stem diameter, plant height, number of fruits per spike, spike length, spike length from node, number of branches per plant, number of spikes per plant, grain weight per plant, harvest index and yield in kg ha^{-1} (Table 3).

Table 3. Mean, coefficient of variation, mean squares and statistical significance of the F values of the combined analysis of variance (seven environments) of 11 variables. Toluca Valley, 2017.

SV	DF	PSP	DT	AP	NFE	LE	LEN	NRP	NEP	PGP	IC	R
Environment (E)	6	1147.48**	82.53**	616.49**	76.61**	64.65**	160.54**	500.47**	391.51**	392.44**	106.72**	369.93**
Repetitions/E	14	0.13	0.01	0.13	0.01	0.06	0.05	0.14	0.09	0.37	0.04	0.36
Accession (C)	31	8.56**	8.4**	18.9**	8.54**	8.39**	17.2**	12.96**	13.5**	19.6**	13.1**	20**
C*E	186	8.19**	6.01**	7.41**	4.02**	2.67**	4.25**	5.22**	5.38**	7.35**	4.02**	7.27**
Error	434	81.81	8.37	61.11	14.05	31.94	2.84	2.09	108.11	4.224	14.43	108 381
Mean		37.87	8.88	90.61	12.79	28.13	15.59	16.63	41.64	5.66	18.11	924.29
CV (%)		23.88	32.56	8.63	29.28	20.09	10.81	8.68	24.97	36.287	20.98	35.61

PSP= dry plant weight; DT= stem diameter; AP= plant height; NFE= number of fruits per floret of main spike; LE= spike length; LEN= spike length from node; NRP= number of branches per plant; NEP= number of spikes per plant; PGP= grain weight per plant; IC= harvest index; R= yield.

Table 4 shows that, although RSL surpassed the rest of the localities in plant height, RSL1 showed the highest dry weight per plant, grain weight per plant and yield. RSL, RSL1, SFT and XAL have statistical similarity in spike length from node and number of fruits per spike. RSL, RSL1 and SFT surpass the rest of the localities in number of spikes per plant. RSL and RSL1 have greater spike length and number of branches per plant. This allowed establishing that the best behavior occurred in the RSL and RSL1 localities, which profiles this site as a potential area to promote the development of the crop of chia. The differences in the productive parameters of the crop of chia in the evaluated localities can be attributed to the fact that the conditions of each locality can influence the development and production of the collections (Durán *et al*., 2016), although the genotype effect is the most marked (Busilacchi *et al*., 2013).

Table 4. Comparison of means among localities (Tukey *p*≤ 0.01).

Environment	PSP	DT	AP	NFE	LE	LEN	NRP	NEP	PGP	IC	R
CPB	7.606f	8.45c	62.72f	8.71b	22.476 d	12.48c	12.49d	21.03c	1.572 d	20.71b	374.73de
CPB1	9.281f	7.61cd	69.66e	9.59b	25.04cd	13.82b	13.8c	22.33c	1.98d	22.88a	316.35f
RSL	55.05c	11.93b	111.5a	15.79a	33.97a	17.16a	20.28a	63.17a	8.324 b	15.13d	1 333.35b
RSL1	86.42a	7.45cd	106.8b	15.74a	33.75a	17.16a	20.35a	63.16a	13.02a	15.33d	2 083.11a
SFT	66.56b	13.4a	109.24ab	15.44a	30.72b	17.1a	18.2b	64.38a	7.54b	12.68e	1 206.88b
XAL	23.75d	6.83d	92.97c	14.88a	26.14c	17.78a	17.75b	34.59b	3.89c	17.46c	623.29c
SJX	16.44e	6.55d	81.338d	9.439b	24.81cd	13.66b	13.58c	22.83c	3.32c	22.6ab	532.37cd

PSP= dry plant weight; DT= stem diameter; AP= plant height; NFE= number of fruits per floret of main spike; LE= spike length; LEN= spike length from node; NRP= number of branches per plant; NEP= number of spikes per plant; PGP= grain weight per plant; IC= harvest index; R= yield; CPB= Cerrillo Piedras Blancas, CPB1= Cerrillo Piedras Blancas 1; RSL= Rancho San Lorenzo; RSL1= Rancho San Lorenzo 1; SFT= San Francisco Tlalcilalcalpan; XAL= Xalatlaco; SJX= San Juan Xochiaca.

In relation to accessions, in Table 5, selections 1 (black seeds) and 12 (white seed) stand out in grain weight per plant and yield (exceeding 1 400 kg ha^{-1}), the weight of seed influences the yield, the marbled gray and white seeds are the heaviest compared to those of uniform brown color (Rovati *et al*., 2012). Materials 19 and 23 showed seed weight per plant and yields of less than 50 kg ha^{-1}, genotypes affected by frosts in full flowering, it would be convenient to evaluate them in areas with less risk of frosts or modify the sowing season because the plant is sensitive to low temperatures (González, 2016).

Table 5. Means of agronomic variables of chia grown in seven environments.

A	PSP	DT	AP	NFE	LE	LEN	NR	NEP	PGP	IC	R
1	48.68ab	8.56de	100.26a-d	12.15bc	31.75bc	15.25d-i	14.55i	46.34a-h	8.66a	18.52b-g	1 403.8a
2	45.62a-d	8.95cde	102.319abc	11.66bc	29.88nc	17.22a-d	16.56b-h	53.28ab	6.41a-d	16.49e-h	1 043.2a-d
3	42.56a-d	8.24ed	103.84ab	10.74bc	28.55bcd	15.89b-g	18.07ab	48.79a-f	5.95cd	17.3c-g	972.4bcd
4	35.863c-h	7.53e	94.86b-i	20.26a	42.07a	12.886jk	18.05ab	33.96g-l	6.67a-d	19.97b-e	1 087.5a-d
5	35.17c-h	8.55ed	92.05d-j	11.61bc	34.25b	14.31h-k	17.43a-f	32.84h-l	6.37a-d	18.51b-g	1 037.9a-d
6	36.897b-h	12.58abc	99.27a-f	14.14b	30.76bc	14.46h-k	16.24b-i	37.13d-l	6.99a-d	20.01b-e	1 141.1a-d
7	36.633d-h	13.46ab	105.38a	12.54bc	28.75bcd	15.45c-h	17.73a-d	33.66g-l	6.54a-d	19.94c-e	1 071.2a-d
8	44.828a-d	11.53a-d	101.97a-d	14.48b	26.72cd	16.38b-f	18.66a	42.45b-k	7.19abc	17.84b-g	1 175.6abc
9	34.929d-h	13.93a	91.2e-k	13.45b	26.16cd	16.73a-e	16.96a-g	26.86	5.23cde	18.36b-g	854cde
10	30.082gh	7.45e	86.61i-k	14.71b	26.61cd	16.98a-d	16.46b-h	28.91 kl	4.86cde	19.98b-e	797.7cde

A	PSP	DT	AP	NFE	LE	LEN	NR	NEP	PGP	IC	R
11	40.091a-g	8.86cde	93.05c-i	20.21a	30.56bc	18.72a	16.43b-i	42.77a-j	6.65a-d	20.4a-e	1 091.9a-d
12	47.378abc	8.92cde	93.25c-g	13.29bc	28.22bcd	15.22d-i	16.48b-h	49.79a-d	8.9a	19.46b-f	1 444.7a
13	38.939a-g	7.98de	97.89a-g	11.211bc	26.44cd	15.87c-g	17.59a-f	40.49b-l	4.73cde	16.086e-i	777.9cde
14	31.273e-h	7.23e	85.76i-l	12.96bc	27.95bcd	16.32b-f	15.97d-i	35.8e-l	6.53a-d	22.58ab	1 064.9a-d
15	26.496h	7.18e	81.18kl	13.14bc	29.38bc	16.26b-f	15.82e-i	29.41jkl	6.2a-d	25.37a	1 014.7a-d
16	34.056d-h	7.82de	80.69l	13.22bc	29.65bc	17.88ab	14.89hi	55.31a	6.39a-d	18.61b-g	1 039a-d
17	37.185b-h	8.61de	85.29i-l	13.43b	29.65bc	15.29d-i	15.74ghi	53.39ab	3.06ef	11.35i	502.3ef
18	38.931a-g	9.04cde	89.03f-l	11.99bc	28.09bcd	14.53e-k	17.61a-f	49.07a-e	1.85fg	11.571hi	306.5fg
19	41.537a-g	9.98b-e	91.38e-k	10.29bc	21.66d	14.32f-k	18.55a	30.96i-l	0.11g	14.6f-i	20.8g
20	38.722a-g	7.5e	91.38i-l	12.25bc	26.71cd	17.59abc	16.45b-h	43.69a-i	6.18bcd	19.37b-f	1 006.6bcd
21	41.892a-g	7.59e	91.38jkl	14.56b	27.12bcd	17.55abc	16.11c-i	51.48abc	6.45a-d	21.69abc	1 053.4a-d
22	49.767a	9.37cde	91.38e-l	12.48bc	26.2cd	15.33d-i	16.87a-g	51.74abc	6.35a-d	16.26e-i	1 027.2a-d
23	42.181a-f	9.03cde	91.38a-g	8.51c	21.83d	12.77k	17.65a-e	36.52d-l	0.12g	14.61f-i	45.7g
24	42.498a-e	8.2de	91.38c-i	10.08bc	25.69cd	13.19ijk	17.94abc	52.09abc	6.64a-d	16.6d-g	1 081.1a-d
25	31.057e-h	6.96e	91.38jkl	11.56bc	25.56cd	16.12b-g	15.17gni	35.17f-l	6.12bcd	20.31b-e	1 000.3bcd
26	32.048e-h	7.28e	91.38i-l	11.26bc	28.34bcd	17.78ab	15.16ghi	36.16d-l	4.91de	15.88e-i	800.3de
27	30.354fgh	7.51e	91.38kl	11.38bc	26.87bcd	14g-k	15.27ghi	34.27g-l	4.43d-h	13.96ghi	720.2d-h
28	32.251fgh	8.54e	91.38f-l	12.29bc	26.43cd	15.99b-g	17.35a-f	38.58c-l	6.84a-d	21.58a-d	1 115.8a-d
29	38.889a-g	10.7a-e	91.38g-l	11.26bc	25.15cd	15.8b-g	17.66a-e	47.02a-g	6.12bcd	17.69b-g	991.5bcd
30	34.556d-g	10.63a-e	91.38l	11.65bc	27.21bcd	14.65e-k	16.12c-i	46.24a-h	4.78cde	16.35e-h	781.3cde
31	32.846e-h	7.29e	91.38kl	13.7b	28.91bcd	15.02d-j	14.81hi	38.68c-l	5.62cde	19.28b-f	917.9cde
32	37.695b-h	7.47e	91.38h-l	13.03bc	27.07bcd	13.24h-k	16d-1	49.67a-d	7.31abc	19.03b-f	1 188.7abc

Accessions that exceed yields of 1 000 kg ha^{-1} of seed also exceed 30 flower spikes, 90 cm in height and 34 g of dry weight of plant, it could be deduced that these variables are closely related to seed yield (Karim *et al*., 2016).

The dendrogram shows that, at a Euclidean distance of 200, five groups formed (Figure 1). Set 1 was formed by accessions 17 and 18, which presented physiological maturation at 160 days after sowing, unlike those of intermediate cycle which have their production at 150 days. Production is low, 306 kg ha^{-1} (18) and 502 kg ha^{-1} (17), but they are within the yields of the national average of 500 kg ha^{-1} (SIAP, 2019).

Cluster two consisted of accessions 19 and 23, which showed flowering at 160 days, but showed cold damage in the frost season, so their production was minimal, of 20.8 kg ha^{-1} (19) and 45.7 kg ha^{-1} (23), this confirms that temperatures below 5 °C affect the crop of chia (Baginsky *et al*., 2016) and that, in temperate climates, more biomass accumulates and they produce less seed, contrary to when they grow in warm environments, in these conditions they accelerate the reproductive phase and produce more seed (Medina-Santos *et al*., 2019).

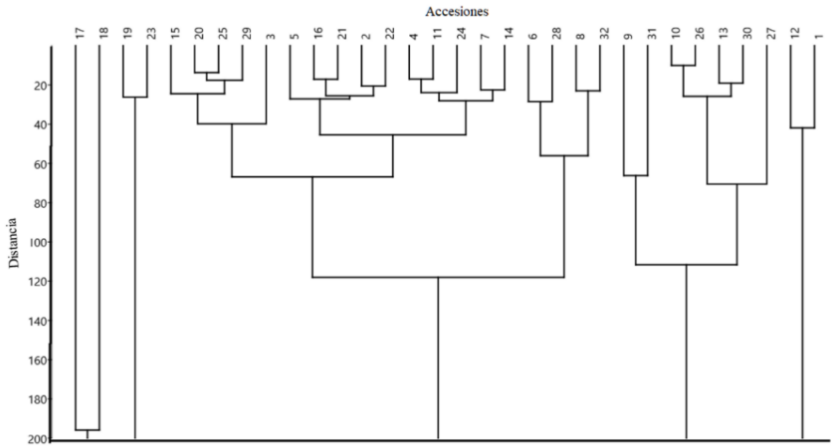

Figure 1. Dendrogram from 12 agronomic variables of 32 chia collections.

Accessions 15, 20 and 25 form a subgroup of cluster three, which can be considered of early cycle, since their flowering occurred at 90 days and their physiological maturity at 120 days, they share the average presence of 15 branches per plant, this subgroup integrates accessions 29 and 3 of intermediate cycle (150 days), with 16 to 18 branches and 47 to 48 flower spikes per plant. With similar seed production, another subgroup consists of accessions 2 (1 043 kg ha^{-1}), 22 (1 027 kg ha^{-1}), 5 (1 037 kg ha^{-1}), 16 (1 039 kg ha^{-1}) and 21 (1 053 kg ha^{-1}). Accessions 7 and 14 share the same production 1 071 kg ha^{-1} and 1 064 kg ha^{-1} respectively, the grain weight per plant 7 (6.54) and 14 (6.52) and number of flower spikes per plant 7 (33) and 14 (35).

Group four was formed by accessions six (1 141 kg ha^{-1}) and 28 (1 115 kg ha^{-1}), which form a subgroup sharing the same grain production and weight per plant, another subgroup is formed by collections 8 and 22 with yields of 1 175 and 1 188 kg ha^{-1} respectively, as well as the same grain weight per plant. The subgroup formed by accessions 10 and 26 share stem diameter (7.2 mm), spike length from node, seed production per plant and yield. Another subgroup formed by accessions 13 and 30 has the same seed production per plant (4.7 g), yield per hectare of 777-781 kg and number of flowers per floret in spike. Similar yields of the accessions of this group have been obtained in Petacal, Jalisco with local cultivars (Sosa-Baldivia *et al*., 2017).

Cluster five was integrated by accessions 1 and 12, which were the ones that had the highest seed weight per plant and production, with yields exceeding 1 400 kg of seed per ha. Fruit or seed production and yield are variables that allow determining the ideal genotypes to implement in the search for cultivation areas (Bochicchio *et al*., 2015).

Principal component analysis

The first four principal components explain 74% of the agronomic variability of 32 accessions of *S. hispanica*. Sánchez (1995) mentions that this percentage is reliable to properly interpret the correlations that exist between them. The first component with 30.43% was related to yield. The second component with 21.39% was defined by the variable of seed weight per plant, the third principal component 12.25%, defined by the number of spikes per plant, and the fourth component with 10.24 of the variability generated by spike length, they collected the variation not gathered by the first, presenting the highest factorial coefficients.

In principal component analysis, the new factors (or components) are independent of each other, that is, a variable must have high coefficients with only one factor and there should be no factors with similar coefficients (Restrepo *et al*., 2012). The variables yield, grain weight per plant, number of fruits per spike, number of spikes per plant and spike length have a positive and significant contribution, which allows specifying the contribution of the variables to the principal components and their relationship with the explained variation (Figure 2). The variables studied tend to be grouped, with an acceptable degree of agreement in their location within the quadrants (Olivares and Hernández, 2020).

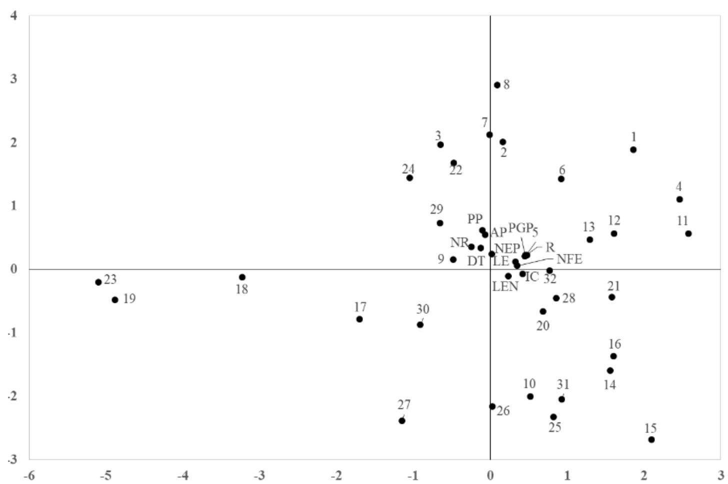

Figure 2. Multidimensional representation of the two principal components of 32 collections of *S. hispanica.*

Conclusions

The characterization showed that there is a wide agronomic variability between the accessions evaluated, the factors yield, number of spikes, seed weight per plant and plant height are variables that allow the best materials to be selected; selections 1, 2, 12 and 22 have outstanding agronomic characteristics, which can be established with potential yields attractive to producers in the study area, sowing in a timely manner when the rainy season begins and thus avoid frost damage or as a basis for developing genetic improvement programs for *S. hispanica* L.

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